THERAPEUTIC ELECTRICITY

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THERAPEUTIC ELECTRICITY

AND

PRACTICAL MUSCLE TESTING

BY

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LONDON

J. & A. CHURCHILL

7, GREAT MARLBOROUGH STREET

1899

PREFACE

Therapeutic electricity is the utilisation of electrical energy for remedial and diagnostic purposes, by applying it *directly* to the living body; that is to say, by placing the body in the path of an electric current. If, therefore, the electric cautery, the electric illumination of cavities, and similar points, are dealt with in this Manual, it is not because such subjects legitimately lie within its scope, but because in the absence of a special treatise thereon it is found convenient to include them here.

Like others who have preceded him, the present writer finds it difficult to decide where to begin. In this "age of electricity" it might be reasonable to assume a certain amount of elementary electrical knowledge on the part of the reader; or it might be considered sufficient to refer him for the required information to the usual electrical text-books. Either course would materially lighten the present volume; but neither has been adopted. It has rather been attempted, by careful selection and condensation, to gather together into the smallest possible compass all those points, and those points only, which are essential to the medical man who practises therapeutic electricity; leaving it to himself to extend that knowledge as occasion offers.

The drawings of motor points are after those of Dr. Castex which appeared in the 'Archives d'Électricité Médicale,' 1895, p. 394; and the writer is indebted to Professor Bergonié for permission to make this use of them.

Mansfield Street, W.;
November, 1899.

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THERAPEUTIC ELECTRICITY

INTRODUCTION

The scope and value of electricity in medicine.

This manual deals with electricity solely from its medical aspect. But the practitioner of medicine must in the first instance travel over ground that is not exclusively his own. In therapeutic electricity, as in other branches of applied electrical science, electricity owes its usefulness to the fact that it offers a ready and rapid means of transferring energy from one point to another.* The electrical engineer by various devices transforms chemical, mechanical, or other energy into electrical forces, and so makes the former reappear, when and where he will, as light, or heat, or sound, or motion. The medical man similarly transforms the same energy and transfers it; but this time it is destined to reappear as work, in the shape of physiological action, physical effects, or electrolytic change, on the various tissues and organs of the body. It may be trne that for the latter pnrposes no very profound acquaintance with electrical phenomena is absolutely required; still it is quite certain that the better the physician is acquainted with the fundamental principles of electro-physics the better he will be able to turn them to account.

There was a time, and it is not long ago, when electricity

* S. Thompson.

was regarded only as a muscle-contracting stimulus, it was measured "by cells" instead of by definite electrical units, its sedative effects were overlooked, its cataphoretic power was ridiculed, its influence on nutrition was unknown. With an increasing knowledge of electrical phenomena and a wider conception of biological physics, views and methods are both undergoing change. Physiologists now begin to recognise that chemical and electrical processes are inseparable from those hitherto called "vital," and that electromotive force is very commonly the outcome of physiological action. Based on such conceptions, therapeutic electricity now stands upon a higher level and advances along broader lines; and nothing is more evident than that the only one competent to use it is the duly instructed medical man. An improved instrumentation is at hand to help him. The use of the galvanometer, the rheostat, the current selector, the voltmeter, and the commutator are now the commonplaces of electro-therapeutic work. The modern induction coil, the "combined battery," and the current controller * are an astonishing advance on the battery of Daniell elements which, fifty years ago, Remak was obliged "to take to pieces and clean daily." Every form of electrical energy is now utilised in medicine. The three conventional currents, the "Galvanic," the "Faradaic," and the "Static" are now supplemented, and to some extent supplanted, by electricity in new modalities. In the electric lighting currents that pass his door, the medical man finds unfailing sources of electrical supply, of unlimited usefulness, and novel power. From the lead of an ordinary incandescent lamp he helps himself to an ever-ready supply of electrical energy, either of a continuous or of an alternating kind. The former furnishes a current which, used through a proper controller † will do for him all that the uniform flow of the galvanic cell can accomplish. Passing the same current through a coil he obtains

* For utilizing public supply currents.

† See p. 73.

that dis-symmetrical alternating current universally familiar as the current of the medical induction apparatus. Still availing himself of the same supply he heats his cautery, lights an exploring lamp, or charges his accumulators; or, passing the current through a motor, he drives his static machine or actuates his therapeutic alternator. The latter can in its turn be arranged to supply a current having all the smoothness and other qualities of that known as "sinusoidal," and with its rapidity, its electromotive force, and even the shape of its electromotive force curve, under absolute control. If the current that is supplied in the street mains be an alternating one, it is passed through a transformer to apply it to the body, to electrise the water-bath, to light the exploring lamp, and to heat the cautery.

The most recent addition to our resources are those currents of great frequency and high potential, under whose influence the respiratory combustions have been shown to increase, skin action to become more active, arterial tension to fall, certain bacilli to die, certain toxines to lose their toxicity. These currents, first experimented with by d'Arsonval, have proved useful in the treatment of rheumatism, gout, asthma, and diabetes.

Thus the scope of therapeutic electricity is widened. Its usefulness is no longer limited to diseases of the nervous system; its procedures no longer confined to localised methods. "L'électrisation localisée," the watchword of Duchenne, now covers only half the ground. The great feature of modern practice is that the latter no longer limits itself to strictly local applications, but that it also resorts to such methods of general electrisation as have a demonstrable influence on the nutritive processes and on cell life; and what the physician aims at by treatment of this kind is so to modify the perverted vital activity of cells and tissues as to strengthen their resistance to morbific agencies, and arouse their inherent recuperative power. This is all that treatment can accomplish. "Cure" is the work of the living cell.

Electrical theory.

Electricity and electrification.—What is electricity? Two hundred and fifty years ago it was a viscous fluid; to-day we are awaiting proof of some universal connecting medium, some "subtle tenuous æther," that will explain electricity, magnetism, and light, perhaps chemical affinity and gravitation. It is only open to us to say that electricity is an invisible agent, unknown excepting by its effects. It is apparently indestructible and uniformly distributed. The text-books of half a century ago follow Franklin in his "one fluid" theory and Symner in his "two fluid" theory. According to the former, electricity is a single imponderable fluid, the particles of which, although they mutually repel each other, attract all matter; and every substance has the capacity for containing a definite quantity of this fluid. When the normal quantity is present no phenomena are manifested; when there is less than the full quantity the body is charged negatively; with more than the quantity the body is charged positively. In other words, the phenomena of electrification depend upon a *plus* or *minus* of the fluid. The "two fluid" theory assumes that there are two kinds of electricity, and these are compared to fluids. They are self-repellent, but mutually attract. They both attract matter. In an unelectrified body they coexist in equal quantities and neutralise each other. The act of separating these fluids constitutes the phenomena of electrification. These fluids are distinguished as positive and negative, and by the signs plus and minus.

Whatever it may be, electricity is certainly not a material fluid: it has no weight, and it is impossible to imagine a substance which is self-repellent.

The fluid theory gave place to the view that electricity is "a form of energy." Now energy, like matter, is indestructible, and so apparently is electricity; but it is not true to say of any particular form of energy that it is indestructible. It is obvious that any form of energy as such can be created by being transformed *from* some other form or destroyed by

being transformed *to* some other form; for example, heat is generated at the expense of motion destroyed. The point, therefore, arrived at is this. *Electricity* is *not* a form of energy, and little can be stated positively of its true nature. But electrical phenomena, *i. e.* electrostatic action, electromagnetic action, electrical waves—what, in short, is called *electrification—is* a form of energy, and can be made to appear and disappear; and a great deal is known of it and of the laws under which it operates.*

According to present views electricity is regarded as closely connected with the æther. Perhaps it *is* the æther—that (still hypothetical) æther that fills all space, and pervades all bodies, and acts as the medium by which the movements of all bodies are carried on,—"the transmitter of all motion and energy." Now taking for granted the existence of an æther, it is assumed, according to one view, that the atoms of all substances are kept together by lines of electrostatic force, lines existing in the æther; that, amongst other things, what is known as chemical affinity is nothing else than this electrostatic attraction (Fitzgerald). This leads to the conception that all electrification is produced by separating the atoms of bodies. Such an operation clearly involves two factors: (1) the effort to electrify, *i. e.* the overcoming the power of the atoms of bodies to cling together, and (2) resistance to being electrified, this resistance consisting of the persistence of the particles to cling together. If by means of friction or chemical action the atoms are separated or drawn asunder, these connecting lines of electrostatic force attached to the atoms are drawn out or stretched like elastic bands, and space (*i. e.* the intervening æther) thus becomes filled with lines of electrostatic force uniting the positively and negatively electrified bodies, each connecting line having a unit of positive electricity at one end and a unit of negative electricity at the other (Fig. 1). These connecting lines, as already stated, are attached to atoms, therefore, although such lines

* Wright.

exist in æther, they always begin and end on matter. These elastic lines of force represent hypothetical lines in the æther along which "stress" exists, *i. e.* the æther is strained; in

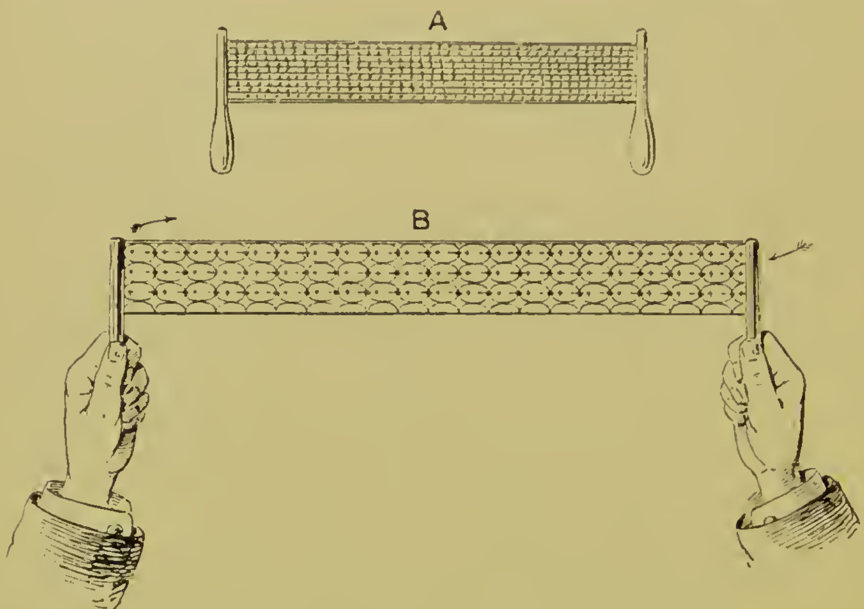


FIG. 1.—Diagram to illustrate strain in the æther.

other words, there is an elastic yielding in it from which it always has a tendency to recover.

There are now signs that this theory of the æther has in its turn had its day, and is giving place to a "rotationally elastic fluid æther" (Larmoor). According to Prof. Hicks and others, "there are difficulties especially connected with reflection and refraction which decide against any theory which imposes on the medium the quality of solidity. On the other hand, a rotational theory seems to meet such difficulties. This theory attempts to show that the æther may possess such elasticity as will enable it to transmit undulations of transverse type" (waves of light and electricity), while "at the same time it allows masses of matter to move freely in it as if it were a gas." The rotation of a fluid in vortices seems to be the only way in which it can be imagined that the æther "may acquire the necessary quasi-rigidity without actually becoming a solid." The theory of electricity, therefore, is so far the theory of the æther.

Such views are touched upon here to bring home to the mind the fact that the electrician does not deal with a material substance but rather with a condition; that in the therapeutic application of electricity no material substance passes through the body; that the electrification of matter does not involve "the addition, removal, or transfer" of any material thing.

Having said this much, it is not proposed again to venture upon the changing quicksands of electrical theory, but to revert at once to the well-beaten track; in other words, to fall back upon that conventional phraseology which is founded upon an imperfect analogy between an electric current and a fluid flow. Therefore, having satisfied ourselves that electricity is not a fluid, that electrical energy travels not by the conductor but by the æther, that electrification is not a substance but a condition, we at once proceed to speak of "the electric current," of "the electrostatic flux," of the "electro-magnetic flux," of "the conductor which forms a path for the current," of "the pressure which forces electricity through a circuit;" and we now use this language with an easy mind, for we do it with the proviso that such phrases are not intended to be an expression of actual facts, but only a means of "elucidating phenomena."

PART I

CHAPTER I

ELECTROMOTIVE FORCE (E. M. F.)

(*"Pressure;" "Potential;" "Difference of Potential;" "Voltage"*)

E. M. F. SUPPOSE two vessels (A and B, Fig. 12), upon the same level, equally full of water and connected by a pipe;—no current flows from one to the other. But place the vessels at different levels, that is to say place B in the position of B′, a current is established from the higher to the lower through the pipe. In a similar manner electricity will flow from the higher (positive) potential to the lower (negative) potential, and the pressure which urges the current forward is called electromotive force (E. M. F.). This force will depend upon the extent of difference of potential (level). Carrying further this water analogy, suppose the driving force to be not a difference of level but a pump;—if the discharge pipe be carried round a given circuit back to the source of supply, both pump and pipe being full of water, the movement of the pump will cause the water to flow and produce a continuous current (Fig. 2). The motion of electricity resembles the current through this pump, and is subject to the same conditions, viz. that at every instant as much flows out of a given closed circuit as flows into it. For the pump substitute an electric generator, say a galvanic battery or a dynamo, and a wire for the pipe, and electricity for the water, we have a tangible conception of an electric current. Placing side by side the electric with the hydraulic terms, it would be said that a certain number of pounds of pressure (volts) are required to

overcome the friction (resistance) of the pipe (wire) in order that the water (electric current) may flow at the rate of so many gallons a minute (ampères). The larger the pipe (wire) the more water (current) could be carried, and the less will

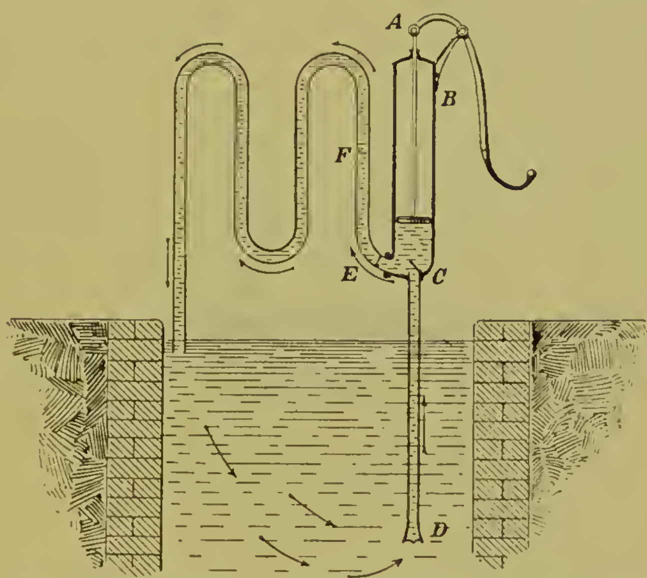


FIG. 2.—Diagram to show analogy between a flow of water driven onwards by a pump and an electric current produced by the E. M. F. of a battery.

be the friction (resistance), and the smaller the pipe (wire) the less the current or gallons per minute (ampères). It is thus that by means of that quality which in hydro-dynamics is called pressure, and in electrical science electro-motive force, a current is forced forwards.

Every electric source, whether a battery, a dynamo, or other apparatus, may be regarded as a device for producing electro-motive force—in other words, for generating a force capable of starting or producing an electric current. All these devices depend upon the law of the transformation and conservation of energy. The methods of transformation for our purpose are (1) chemical (a primary or secondary cell), and (2) mechanical (frictional and influence machines, dynamo-electric machines). There are also other sources of energy capable of producing electrical forces which it is not here necessary to study. For example, the living body of an animal or plant, being the seat of physical and chemical

Sources of electricity.

phenomena, may be regarded as a source of electrical energy. So also is radiation, *i.e.* light or heat, an electrical source, a fact exemplified in the thermo-electric cell, or in the action of light upon selenium.

Of these various sources of E. M. F. the one most familiar to the medical man is the primary or voltaic cell (Fig. 3).

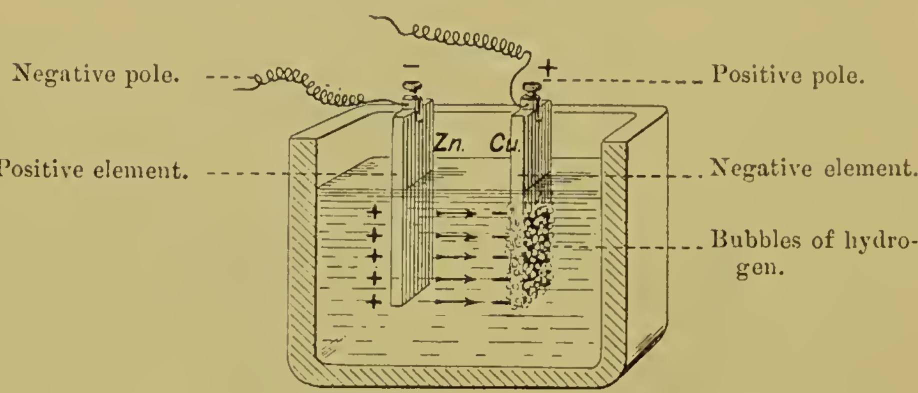


FIG. 3.—A "Voltaic Cell."

Every such cell is made up of (1) a voltaic couple consisting of two "dissimilar electrical conducting substances;" (2) an exciting substance called the electrolyte. If two such liquids or electrolytes are used, the cell is called "a double fluid" cell. The two substances forming the voltaic pair or couple are known as the *elements* of the cell, but sometimes the term element is improperly applied to the couple or pair of elements. It is usual to make voltaic elements in the form of plates or rods, and these are known as the positive and negative elements. Thus supposing that we constitute a voltaic cell by taking two sheets or rods of dissimilar metals, say copper and zinc, immersing them in an acid solution and connecting them by a metallic connection, a wire, the wire will at once manifest certain phenomena known as electrical. It will attract iron filings, it will deflect a magnetised needle, applied to a suitable liquid it will decompose the liquid, applying it to the tongue it will produce tingling or metallic taste. All this has been done by causing an electrical current to flow through the wire: in other words, we have established a *difference of*

potential, and current passes from the plate at the higher potential to the plate at the lower potential, *i.e.* current flows from the zinc to the copper through the liquid and from the copper to the zinc through the wire. Owing to the chemical changes that occur a continuous current is thus kept up in the circuit. A voltaic element may therefore be regarded as a device which by the expenditure of work (*e.g.* chemical change at the expense of a metal), keeps two bodies at different potentials, and thereby produces a flow of electricity through a conductor connecting one with the other. Electricity is, so to speak, liberated at the surface of the zinc; it passes through the fluid of the cell to the copper, and the copper being joined to the zinc by a wire, the current flows through the wire and so completes a circuit. Without a complete circuit the electricity cannot flow. All the parts traversed by the current collectively constitute the circuit; the part of the circuit within the cell is the "internal circuit," the part of the circuit outside the cell is the "external circuit." When the continuity of the flow is broken the circuit is "open;" when the conductor is continuous the circuit is said to be "closed." When the conductor has an exceedingly small resistance the circuit is said to be "short,"—the battery is "short circuited." The plate from which the current flows within the cell is the electro-positive element (the zinc); the plate towards which the current flows is the electro-negative. But the positive *pole* of the cell is the terminal of the electro-negative element, while the negative pole is the termination of the electro-positive element. In other words, in the external circuit the current flows from the copper to the zinc, whilst in the internal circuit it flows from the zinc to the copper. The positive pole is marked +, and the negative pole is marked −. When the cell is in action, *i. e.* when it is furnishing an electric current, a chemical action is taking place between an electrolyte and one of the plates (the positive) which enters into combination with part of the electrolyte. The negative plate is

not acted upon, but as the result of the decomposition of the electrolyte there is a tendency to evolve hydrogen at the negative plate; and if this be allowed to accumulate, the ability of the cell to furnish a current is materially decreased. And this decrease occurs not only because the film on the copper increases the internal resistance of the battery, but because the accumulation of hydrogen may for the moment be regarded as transforming the copper plate into a hydrogen plate, and hydrogen being electro-positive to zinc a current is set up opposing the original one; this is called a counter-electromotive force (C. E. M. F.). This accumulation of hydrogen is called polarisation, and when a cell "gives out" from this cause it is said to be "polarised." Various forms of conducting substances, usually metals or carbon, are employed for the couples. Zinc is usually the positive element, the negative being carbon, copper, lead, silver, or platinum.

The Leclanché cell.—That primary cell which for medical purposes is most generally useful is the Leclanché (Fig. 4).

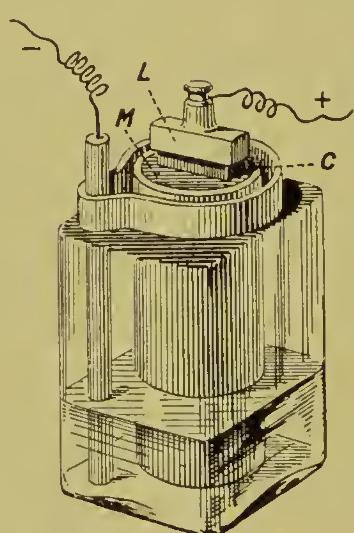


FIG. 4.—A Leclanché cell.

Here the elements are carbon and zinc, and the excitant is an aqueous solution of chloride of ammonium. The chemical energy which produces the E. M. F. is got in the combination between the zinc plate and the solution of ammonium chloride.

The Daniell cell.—In that form of Daniell cell known as the "gravity" cell the two elements are zinc and copper; but here there are two separate liquids, viz. a solution of copper sulphate which occupies the lower part of the cell, and a lighter solution of zinc sulphate which surrounds the zinc plates and floats upon the more dense solution of copper sulphate. This is an example of a "double fluid" cell (Fig. 5). The zinc plate dissolves under the action of

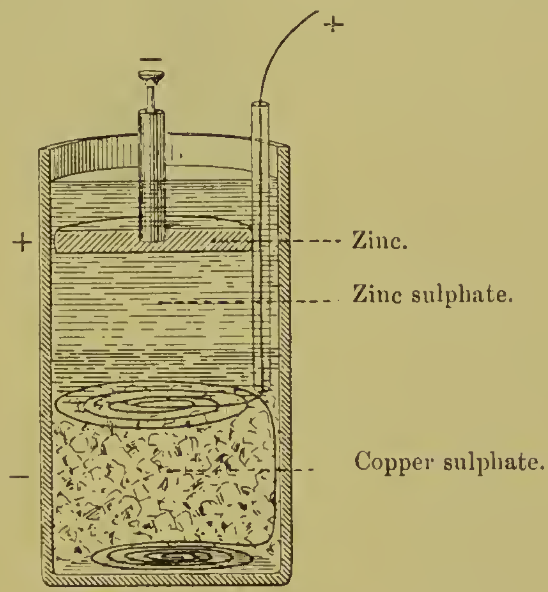


FIG. 5.—A Daniell cell.

the excitant to form zinc sulphate, hydrogen being set free. The latter displaces the copper from its solution and forms sulphuric acid and metallic copper; the acid passing back to the zinc, the copper is deposited upon the negative plate.

The Grenet cell.—The Grenet or bichromate of potash cell has a higher E. M. F. (about two volts) than either of the preceding, and is suitable for furnishing a strong current for a short time, *e.g.* for cautery purposes or for lighting small lamps. The positive element is a plate of zinc; the negative element consists of two plates of carbon. The depolariser is chromic acid (Fig. 6).

The persulphate of mercury cell is one having zinc and carbon as plates and persulphate of mercury as the excitant.

The chloride of silver cell is a small cell hermetically sealed, whose elements are zinc and silver chloride. The two plates

FIG. 6.—A Grenet cell.

are separated by sheets of blotting-paper and saturated with a solution of chloride of zinc.

The Edison-Lalande cell, an excellent cell for cautery or motor work, has its elements of zinc and copper; copper oxide being the depolariser, and the excitant being caustic potash. To prevent the formation of a carbonate by contact with the air a little heavy paraffin oil is poured over the top of the potash solution.

The Grove and modified Bunsen cell.—The elements are zinc immersed in sulphuric acid, and baked carbon in nitric acid.

The "dry cell."—The term "dry" is not altogether appropriate, for although this class of cell does not contain free liquid, its action depends on the presence of a liquid electrolyte held by some absorbent material such as paper pulp, cotton, sawdust, &c.

The Hellesen or dry Leclanché is one of these cells (Fig. 7). The positive element is a casing of zinc; the negative is a carbon rod, which stands in the centre of the zinc cylinder. The depolariser is oxide of manganese. Cells of this class are much used on account of their portability.

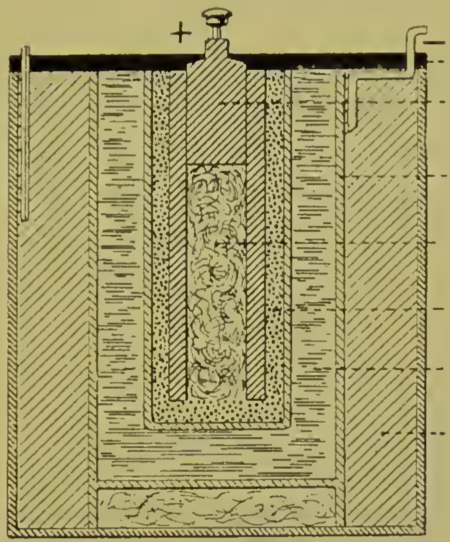


FIG. 7.—Hellesen dry cell.

The following table gives the E. M. F. of various cells :

Grenet . . . (E. M. F.)	2·1
Grove	1·93
Bunsen	1·87
Sulphate of mercury . . .	1·6
Leclanché	1·48
Hellesen dry cell	1·45
Daniell cell	1·07—1·1
Silver chloride	1·04
Edison-Lalande	0·78

The secondary cell or accumulator.—The prominent difference between an ordinary cell and a storage cell is that in the former, when the positive plate or the electrolyte is consumed the cell ceases to supply current until these are renewed. In a *secondary* cell the elements and electrolyte are such that after the cell is run down it can be charged again by passing an electric current through it. In the ordinary type of storage cell the plates have perforated grids, the latter being filled with a mixture of red lead and sulphuric acid on the positive plate, and a mixture of litharge and sulphuric acid on the negative plate. When a continuous current passes through these, the lead sulphate

is decomposed, causing oxygen to appear at the positive plate, and hydrogen at the negative. The positive is thus peroxydised, and lead di-oxide formed. The negative is deoxidised, and spongy metallic lead is the result. When these changes have occurred, the cell is then said to be charged. When the cell is called upon to give out current the dioxide loses oxygen, and the spongy lead becomes oxidised, so that they are both reduced to the same condition, and must be polarised or "charged" again. For the principle of this action see "polarisation of cells," p. 12. The electrolyte is dilute sulphuric acid, sp. gr. 1·50 to 1·70. Charging is usually done by connecting the battery with the terminals of a dynamo, the positive terminal of the battery being attached to the positive terminal of the dynamo, and the negative terminal of the latter to the negative terminal of the battery. By having an ampèremeter in circuit, and looking at it about every hour, and taking an average of the observations, the charge is easily ascertained. Instead of a dynamo a continuous current from a battery is sufficient, but of course the latter must be at a higher electromotive force than two volts, as the opposing polarisation current of the accumulator has to be reckoned with. The advantage of storage cells is that they can supply a very powerful current at a steady pressure until the cell is nearly exhausted. Further, the cell always stands ready for action without the necessary raising and lowering of the elements, as in the bichromate battery. The capacity of an accumulator is measured in ampère hours, viz. the product of the number of ampères the cell can furnish into the number of hours during which it can maintain that discharge, *e. g.* a thirty ampère hour accumulator would give one ampère during thirty hours, two ampères for fifteen hours, and so on; but too rapid a discharge injures the cell, and therefore its proper discharging capacity must, in the first instance, be ascertained. "Flashing" the cells, *i. e.* connecting their poles through a short wire to see if they are in working order, is deleterious. It is

stated that a good accumulator ought to be able to supply 5—10 ampère hours for each pound of lead. The E. M. F. of such cells is two volts; their internal R. almost *nil*. Test for voltage by voltmeter, and if the voltage falls much below 2, say to 1·8, the accumulator requires re-charging, and will be injured by further use until this is done.

The Lithanode (Fig. 8) is an excellent battery for cautery,

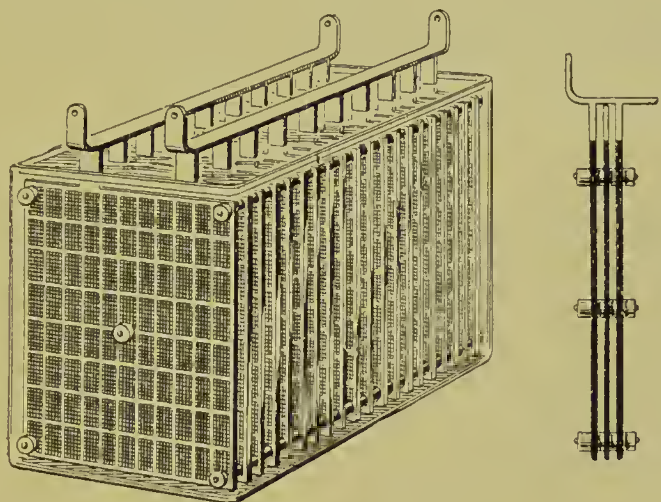


FIG. 8.—The "Lithanode" accumulator.

light, or radiography It belongs to the "cast" type of accumulator, in contradistinction to the "pasted" type; that is to say, the paste is made into slabs, and dried and "formed" before being handed over to the "caster." The latter arranges the slabs in his mould, and metal (not quite pure lead) is run into it. The shrinkage of the metal as it cools binds the slabs together, insuring good electrical contact. It is claimed for this battery that it cannot "buckle" or lose its shape. The plates are threaded on ebonite rods, contact being prevented by porcelain "separators." In the smaller lithanode batteries, such as those used for medical purposes, it is only the positive plate which is of the "cast" type. The weight of a lithanode battery, of 500 ampère hour capacity = 226 lbs., including acid and glass box. For medical and radiographic purposes two six-cell 30 ampère-hour batteries are convenient.

The "Hatch" battery is the latest form of accumulator, and is more or less a new departure. It contains a modification of the ordinary pasted plate cell. The paste is held by a porous earthenware plate, the latter being placed between electrodes of sheet lead. It is claimed that by means of the porous partition the active material is secured in position better than when attached to the lead plate itself. This diminishes weight, and gives the cell a longer life, and risk of injury from a very rapid discharge is said to be lessened.

Resistance (R.)

Resistance.

The current (rate of flow) which a given E. M. F. will send through a circuit depends upon the resistance which opposes the flow of the current. Other things being equal, the greater the resistance the less the current, and the less the resistance the greater the current. This relationship of current and resistance is brought out in Fig. 9.

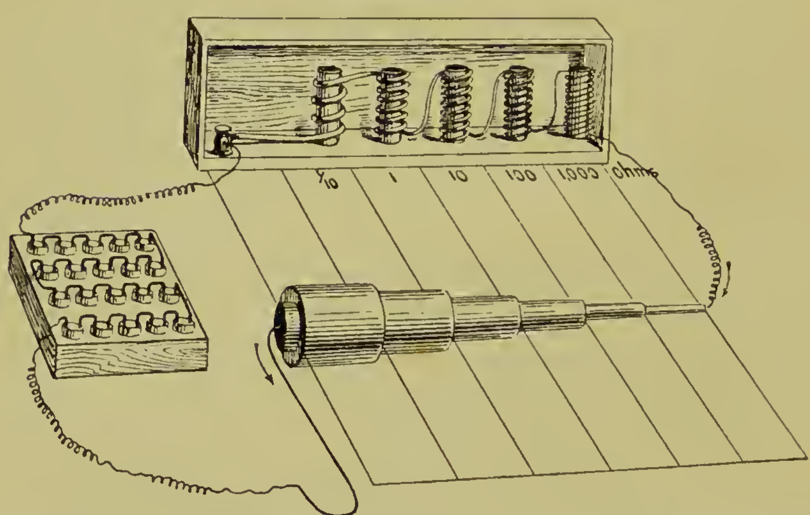


Fig. 9.—Diagram to show ratio of current to resistance (after Massey).

Resistance (R.) is measured in ohms.* The greater the length of the circuit the greater, other things being equal, is

* The resistance of one ohm is equal to the resistance of a column of mercury one sq. mm. in section and 106 cm. long.

the resistance, the greater the area of the cross-section of the conductor the less, other things being equal, the resistance. The material of which the conductor is made is also an important element in resistance; thus a circuit of low R. would be a short thick wire, a circuit of high R. would be a long piece of thin wet string. The temperature of the conductor is also an element of resistance. The ordinary rule is that to increase the temperature of a metal is to increase its resistance. In the case of liquids and non-metallic substances the R. diminishes as the temperature rises. Temperature diminishes the R. of insulators, and carbon in this respect acts like an insulator.

The "specific resistance" of a substance is the R. of a piece of that substance 1 c.m. long and 1 sq. c.m. in area of cross-section. In metals the specific R. is a small fraction of an ohm expressed in millionths of an ohm (microhms); in liquids, as a rule, R. is conveniently expressed in ohms. In substances of low conducting power (insulators) R. is, of course, very high, and may be expressed in millions of ohms (megohms). The resistance of silver is 1·53 microhms; of pure water about 3·7 megohms. But in the case of the latter the addition of some saline substance may reduce it to a few ohms. Materials whose conducting power is inappreciable are called insulators. The R. of the human body is considered at p. 94.

Intensity or "Current"

(*"Rate of flow;" "Ampèrage"*)

Every electric current presents two great features or qualities; one of these, viz. pressure or electro-motive force, has already been examined. The other is rate of flow or volume. This is known as current strength or intensity, or simply "current." In England the latter is the commoner term. In practical work the unit of "Current" is the ampère, hence ampèrage is synonymous with current. Intensity or "current."

The measurement of Intensity ("current").

There are several methods of measuring the intensity of an electric current :—

(1) When a current is passed through an electrolyte, say a metallic solution, or water, decomposition takes place, and this is termed electrolysis. Thus suppose the electrolyte to be a solution of copper sulphate;—on passing the current through it, metallic copper is deposited on the terminal connected with the negative pole and an acid substance at the terminal connected with the positive pole; and as the amount of decomposition will depend upon the quantity of electricity, the latter may be measured by the amount of electrolytic decomposition that has taken place. Or suppose the electrolyte to be water, a current is passed, and the water is decomposed into its component gases; the oxygen appearing at the positive pole (anode), the hydrogen at the negative pole (cathode). Here again, inasmuch as the amount of decomposition depends upon the quantity of electricity, it is evident that, knowing how much gas per minute a given intensity will liberate, a correct measurement may be made of the intensity employed. It is known that a current of one milliampère will liberate 10·3 cubic millimetres of these gases in one minute; therefore a scale can easily be constructed showing by the amount of gas liberated, the number of milliampères of current used. Such an instrument is known as a voltameter, and the method as the voltametric method (Fig. 10).

(2) When a current encounters resistance, as, for example, in passing along a thin wire, the wire is heated in proportion to the strength of the current. This is the calorimetric method.

(3) When a wire carrying a current is brought near a magnetised needle the needle is deflected in proportion to the strength of the current. On this principle the ampèremeter or galvanometer is constructed; and this, known as the galvanometric method, is the one most commonly used for medical purposes.

(4) Intensity can also be calculated by Ohm's law (see p. 23).

The medical galvanometer (Edelmann's), shown in Fig. 57, is graduated in milliampères and will give readings by means of "shunts" up to 500 milliampères. A "shunt" is a

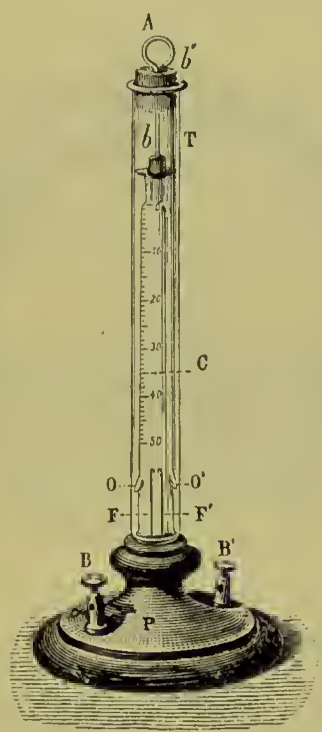


FIG. 10.—Voltameter.

means of passing a certain definite proportion of current, usually nine-tenths, round by another way, so that it will not influence the magnetised needle. The remaining one-tenth, therefore, when the shunt screw is screwed home, is the only amount registered; but the whole current goes through any conductor, *e. g.* a patient's body, that may be in circuit. The registered amount must, therefore, be multiplied by ten to arrive at the proper strength. The shunt screws are marked one-tenth, or one-hundredth, or whatever amount of current they allow to pass. In the galvanometer or milliampèremeter (shown in Fig. 57) the dial gives readings of from 1 to 500 milliampères. The same

instrument having a means of putting in a resistance of 1000 ohms can also be used as a voltmeter, inasmuch as one ampère multiplied by one ohm gives the unit of E. M. F. In this instance it is milliampères that are registered, therefore the R. must be correspondingly made 1000.

In the Gaiffe galvanometer of M. d'Arsonval (Fig. 11), a

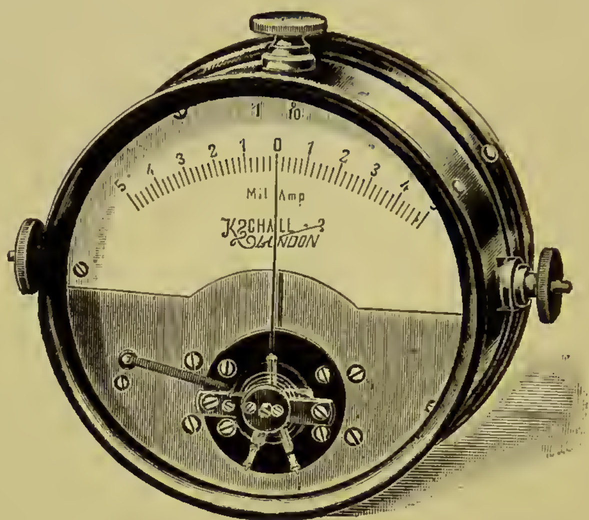


Fig. 11.—Milliampèremeter.

coil of insulated wire having a soft iron core, is suspended between the poles of a fixed magnet; and the fixed magnet, and the soft wire magnetised by influence, produce such a powerful action on the suspended coil as to annul the magnetism of the earth.

Another instrument free from the earth's magnetism is the Weston ammeter. Here, also, there is a permanent horseshoe magnet and a soft, solid, cylindrical, iron core. Between this core and the pole pieces of the magnet is a space in which a delicately suspended coil is free to move. It has the disadvantage that it will not read in both directions. The lower or red scale may be used as a voltmeter when placed in circuit with a small box of resistances which accompany the instrument.

CHAPTER II

Ohm's Law

Reverting to the water analogy: In Fig. 12 the water in vessel, A, may be supposed to exert one unit of *pressure*, and Electrical units.

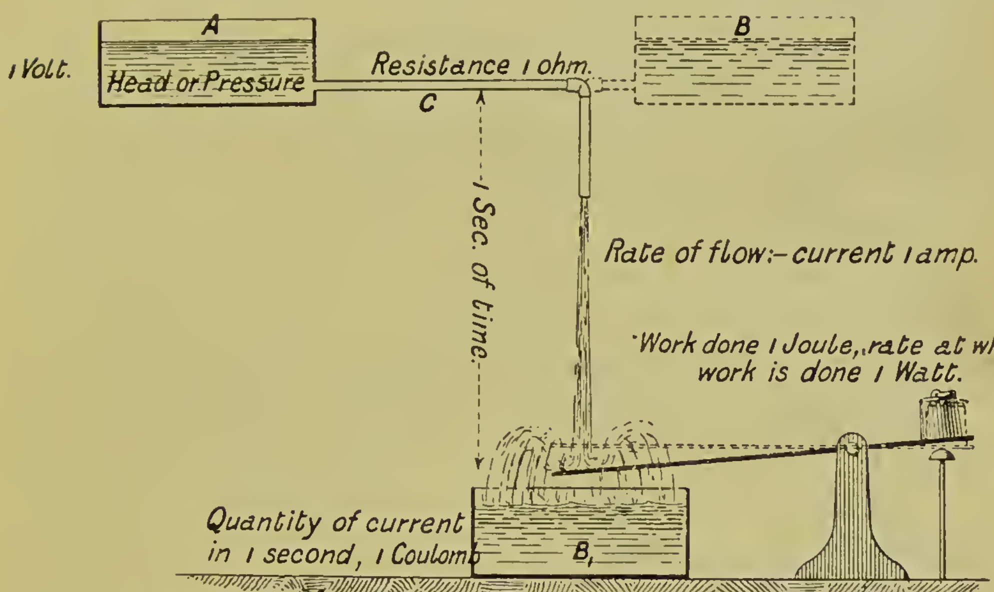


FIG. 12 illustrates the electrical units by means of the water analogy.

this unit in the case of an electrical current we call 1 *volt*. The tube, C, through which the current flows offers *resistance* according to the diameter of the pipe. The unit of resistance, in the case of an electrical conductor, we call 1 *ohm*. With the pressure in question (1 volt) it is this resistance of 1 ohm* which determines the *rate of flow* of 1 *ampère*. This rate of flow having continued for one second will have allowed a quantity of electricity to flow known as 1 coulomb. Now energy (electro-motive force or pressure) cannot be expended

* One ohm is about the resistance of one Daniell cell, and, as already stated, is equivalent to the resistance offered by a column of mercury 1 sq. mm. in section and 106 cm. in length.

in overcoming resistance without doing work. In this instance we have expended 1 volt of pressure at the rate of 1 ampère, and we have done work at the rate of 1 watt. If we maintain the rate for one second we have done an amount of work known as 1 joule. We thus arrive at a definition of electrical units.

The *volt* is the unit of E. M. F. (It will produce a current of 1 ampère where the R is 1 ohm.)

The *ohm* is the unit of resistance. (It limits the current to 1 ampère when the E. M. F. is 1 volt.)

The *ampère* is the unit of current or rate of flow. (It is the rate of flow through a circuit whose R is 1 ohm and whose E. M. F. is 1 volt.) For medical purposes the ampère is inconveniently large, therefore we measure by milliampères or one-thousandths of an ampère.

The *coulomb* is the unit *quantity* of electricity (the quantity delivered by 1 ampère in one second).

The *watt* is the unit rate of doing work. (It is the rate of doing work when 1 volt causes a current of 1 ampère to flow. In other words, the rate of doing work, "activity" is obtained by multiplying volts by ampères. The watt is the volt-ampère.*)

The *joule* is the unit of work. (One unit of work is expended when 1 volt causes 1 coulomb of electricity to pass through a circuit. It is the volt-coulomb, *i. e.* the unit *amount* of work done independently of any time factor. It equals 0·738 pound.)

It is thus evident that these units depend upon each other; the more the pressure the more the ampères,—the less the resistance the more the ampères. That is to say the current varies directly as the pressure and inversely as the resistance.

Ohm's law.

This is "Ohm's law." It is embodied in the following equation, the most important formula in electrical science:

$$\text{Current (ampères)} = \frac{\text{electro-motive force (volts)}}{\text{resistance (ohms)}} \text{ or } C = \frac{E}{R}$$

* 746 watts equal one horse-power.

Example 1.—If the R of a patient's body be 1000 ohms and the E. M. F. 10 volts, what current is passing through him ?

$C = \frac{10}{1000} \frac{E}{R} = \cdot 01$ ampères, *i. e.* 10 milliampères passing through the patient.

If *any* two factors in the equation are known the third can be calculated.

In other words—

If $C = \frac{E}{R}$ then $R = \frac{E}{C}$ and $E = C \times R$

In example 1, knowing E M F and R we have calculated C. Now knowing E. M. F. and C, calculate R.

Example 2.—If a current of ·01 amp. (10 ma.) be passing through a patient under a pressure of 10 volts, what is the R ?

$$\frac{10\ (E)}{\cdot 01\ (C)} = 1000\ R$$

Example 3.—Knowing R and C, calculate E. If the R be 1000 ohms and it be desired to pass a C of ·01, what pressure will be required ?

$E = \cdot 01 \times 1000 = 10$ volts.

Example 4.—If ·01 amp. of current be passed through a patient under a pressure of 10 volts, at what rate will work be done on the patient ?

$\cdot 01\ (C) \times 10$ v. $= \cdot 1$ watts.

Example 5.—If work be done at the rate of ·1 watt, what quantity will be done in 60 seconds ?

$\cdot 01 \times 60 = \cdot 6$ joules.

Another formula, known as the C^2R law, arises out of the law of Ohm, and it is useful in certain calculations. We have seen that $E \times C =$ watts, but $E = C \times R$. Now if we substitute $C \times R$ for E in the first equation, we have $C \times (C\,R) =$ watts or $C^2R =$ watts. The energy expended (in the case of simple conductors) takes the form of heat. But whatever form the energy takes, this law is the means of knowing the work that is being done in one part of a circuit. Rule,

square the current and multiply by the R of the part of the circuit in question.

Example 6.—If with electrodes of a certain size the R of the patient be 1000 ohms and the R of a rheostat in series with the patient be also 1000 ohms, and given a current of ·01 with an E. M. F. of 20 v.; what will be the rate of doing work in the patient? In other words, how many watts are expended on the patient's part of the circuit?

$\cdot 01 \times \cdot 01 \times 1000 = 1 \cdot 0$ watts.

Example 7.—Now suppose the total R to remain the same and, therefore, of course, the C to remain the same, but let the distribution of the R be altered in the patient's part of the circuit from 1000 to 1500 ohms (say by using smaller or worse adapted electrodes), what is the calculation of watts?

$\cdot 01 \times \cdot 01 \times 1500 = 1 \cdot 5$ watts.

It is evident in this case that although the current has remained the same, half as much work again has been done on the patient's part of the circuit, influencing, amongst other things, perhaps the pain felt by the patient. In other words, although the rate of flow is always the same in different parts of the circuit, the rate at which *work is done* is in accordance with the $C^2 R$ law.

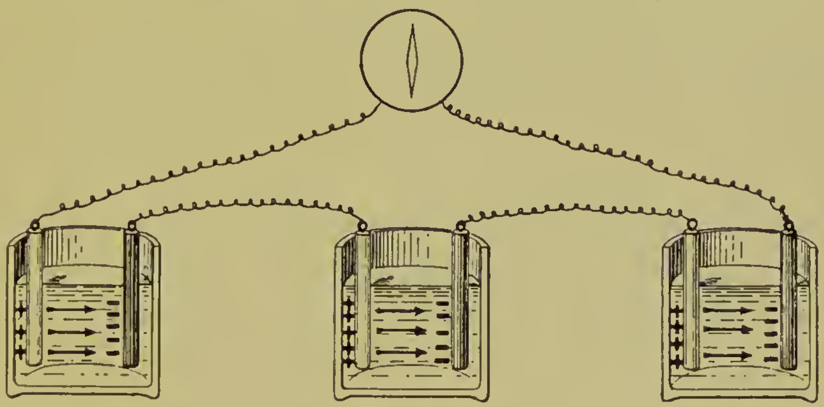
CHAPTER III

How to Measure and Vary E. M. F.

The unit of E. M. F., viz. the volt, can be measured directly on the voltmeter, or by comparison with a standard cell of known E. M. F., *e. g.* the Daniell. Voltage can also be calculated, as already explained, by Ohm's law. **Measurement of voltage.**

It is to be understood that inasmuch as the E. M. F. of a cell depends upon the excitant and the nature of the plates, it cannot be increased by increasing the *size* of the cell. E. M. F. can only be increased by connecting together a number of separate cells, so that they supply their current to the same circuit. Cells so connected together collectively form "a battery." **How to vary E. M. F.**

1. When the highest E. M. F. is required the cells are connected "in series," *i. e.* the negative pole of cell A is connected with the positive pole of cell B, the negative pole of B with the positive of C, and the free negative and free **Methods of connecting cells.**



A. B. C.

Fig. 13.—Cells connected "in series."

positive poles of A and C form the terminals of the battery (Fig. 13). Here the E. M. F. of the series is equal to the

sum of the E. M. F. of the separate cells. Thus, a battery of four Leclanché cells connected in series, each cell having an E. M. F. of 1·5 volts, would have a total E. M. F. of 6 volts.

2. If, on the other hand, cells are connected as in Fig. 14, *i. e.* having their positive poles joined to form one pole of the

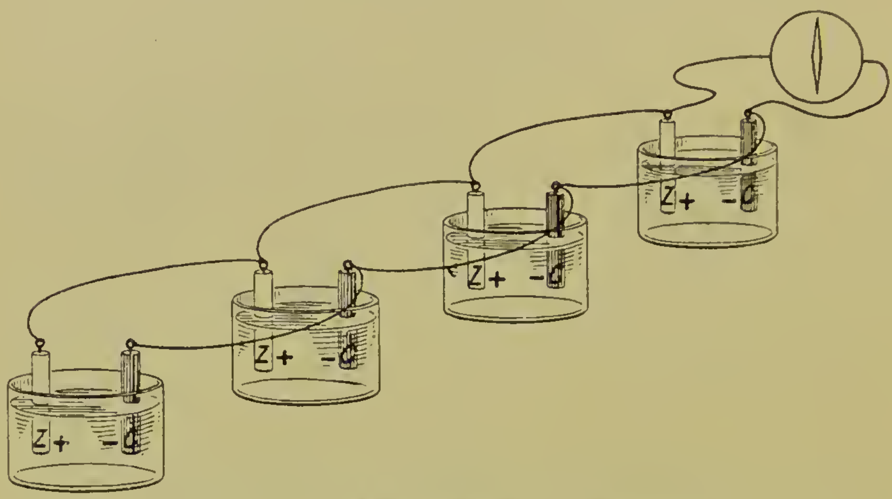


Fig. 14.—Cells connected "in parallel."

battery, and their negative poles joined to form the other pole of the battery, such cells are said to be connected "in parallel." What has been done in this case is to form one large cell by joining the plates of several cells, so that the electro-motive force is the E. M. F. of one cell only, but the internal R will also be the R of one cell only. Therefore, in joining cells in parallel, although the E. M. F. is brought down to the E. M. F. of one of the cells so joined, the total R of those cells is divided by the number of cells. Other things being equal, the R of a cell depends upon the extent of the cross-section of its plates. Now, in this instance cross-section has been increased by joining the plates of the same polarity, therefore resistance is diminished, and brought down to that of one cell.

3. There is a third way of connecting cells, viz. "in groups," *i. e.* some in series, and some in parallel; *e. g.* take four cells, place two in one series, and the other two in another series, join the positive poles of the two groups to form a positive

pole, and the negative poles of the two groups to form a negative pole, the effect of this is to halve the number of cells, and double their size (Fig. 15).

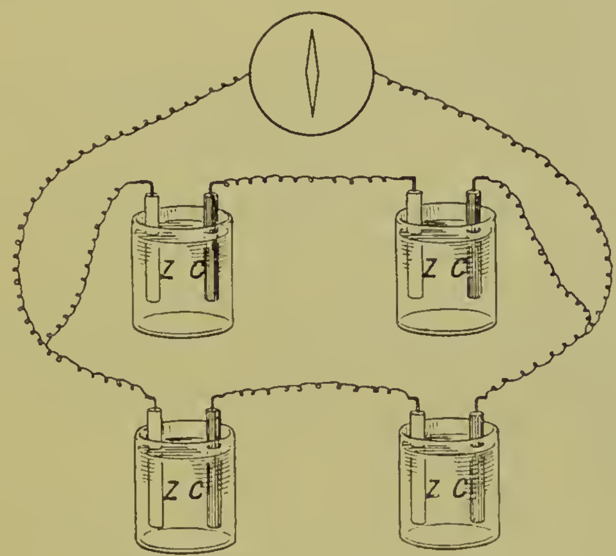


FIG. 15.—Cells connected "in groups."

The above methods of connecting up cells have a very important practical bearing, inasmuch as by their means the battery can be adapted to the kind of work it is called upon to perform.

I. For "*galvanisation*" the R of the external circuit, *i. e.* the R of the human body, is very high, say 1000 ohms and generally more, and to overcome this high R there is required a high E. M. F. Therefore join the cells "in series" (Fig. 13).

II. But for *cautery work* a different set of conditions are met with. The R of the cautery is very low (say 0·05 to 0·1 ohm); there is nothing to be gained by adding E. M. F., so long as R is added at the same time, as would be done by connecting in series. Therefore, instead of increasing current by increasing E. M. F., diminish R, the third factor in the equation, by having large cells of such construction as to give them low internal R (*e. g.* bichromate cells or accumulators), and join them in parallel (Fig. 14). As an example, take an

accumulator having an E. M. F. of 2 volts, with an internal R of 0·05, and a cautery whose R is ·1.

$\frac{2}{0·05 + ·1} = \frac{2}{0·15} = 13.333$ amp., a current sufficient to incandesce a cautery.

III. For *electrolysis of tumours.* Here, as in the previous cases, the question is what is the R to be overcome; *e. g.* in the Apostoli treatment of a uterine fibroid, suppose that the resistance to be overcome is 600 ohms., and suppose it to be desired to pass a current of 100 milliampères; then, as E. M. F. equals R multiplied by C, 60 volts will be required; (600 ohms × ·100 amp. = 60 volts). Taking the E. M. F. of a large fresh Leclanché cell at 1·5, forty such cells joined in series would supply the required E. M. F.

IV. *Lighting Small Incandescent Lamps for Cystoscope, &c.*—The R of the filament is low, say 3 to 18 ohms, current required about 1 ampère. Now taking the R as 10, and the current required being 1, the necessary E. M. F. would be 10 volts. (10 ohms × 1 amp. = 10 volts.)

CHAPTER IV

Various Kinds of E. M. F.

The character of a current varies with the character of the E. M. F. which produces it; and the latter depends upon the nature of the electric source, *i. e.* battery, dynamo, coil, influence machine, or whatever that source may be. An E. M. F. which does not vary in strength, *i. e.* which is uninterrupted, uniform and direct, such for example as that of a voltaic cell, is said to produce a "constant current." The "curve" which represents this E. M. F. is a right line, *a c*, parallel to the axis of the time, *o s* (Fig. 16); and it is evident A "constant" E. M. F.

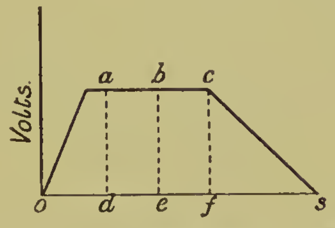


Fig. 16.—A "continuous" E. M. F.

that $a\,d = b\,e = c\,f$. But the constant state represented by *a c* cannot be established at once; it is preceded and followed by a variable period—the variable period of make, and the variable period of break. And these produce excitation according to the suddenness with which they are carried out, *i. e.* according to the length of time taken in establishing or withdrawing the current. Thus in the Fig. 16 the variable state of closure ("make") is represented as less gradual than the variable state of rupture ("break"), and the physiological effects will be correspondingly different.

A "periodic" E. M. F.

A current whose intensity varies regularly and returns to the same value at equal times is called a "periodic current" (Fig. 17). The "period" of such a current is a part of the

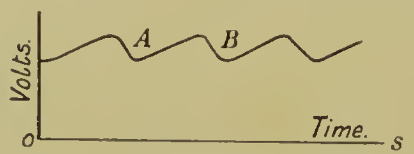


FIG. 17.—A "periodic" E. M. F.

curve comprised between two points, *A* and *B*, similarly placed. The *frequency* is the number of periods a second.

An alternating E. M. F.

An E. M. F. that changes direction as well as magnitude is an alternating E. M. F.; thus in Fig. 18 it is seen to alternate

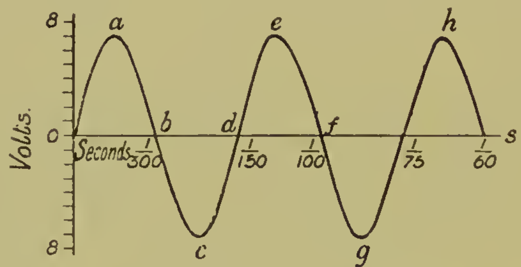


FIG. 18.—An alternating E. M. F. (symmetrical and sinusoidal).

between 8 volts positive and 8 volts negative. In this case the change is made gradually, *i. e.* the E. M. F. gradually rises up to 8 (*a*) in a positive direction, then gradually comes down to zero at *b*, then falling below the line, *i. e.* passing over to the negative side, it attains its negative maximum 8 volts at *c*, then diminishing to zero, which it reaches at *d*, it again changes its direction, and repeating the changes as before produces the E. M. F. shown. The wave *o, a, b*, or *b, c, d*, is called an alternation; a complete wave on each side, viz. *o, a, b*, and *b, c, d*, taken together is called a cycle. The period is the time required for the completion of the cycle. The number of cycles in a second is called the frequency. In the figure shown the positive and negative waves are equal in size and shape, and the E. M. F. is therefore said to be "symmetrical."

Symmetrical E. M. F.

If the outline of the positive wave differed from that of

the negative wave the curve would be dis-symmetrical. An E. M. F. of a dis-symmetrical type is produced by various forms of apparatus of which the medical induction coil is the chief (Fig. 19). Here the E. M. F. of the break current

Dis-symmetrical E. M. F.

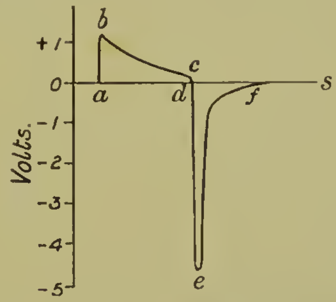


FIG. 19.—Primary induced E. M. F. (dis-symmetrical).

is much greater than that of make, but the quantity of electricity in each case is the same, *i. e.* the area of the surface *a, b, c* = *d, e, f,* but in the latter the current passes in a shorter time.

It thus appears that the graphic representation of an alternating current depends upon the manner in which it changes its frequency, direction, and magnitude.

In galvano-faradisation where the constant and induction coil currents pass through the part at the same time the E. M. F. can be represented graphically, as shown in Fig. 20,

Galvano-faradic E. M. F.

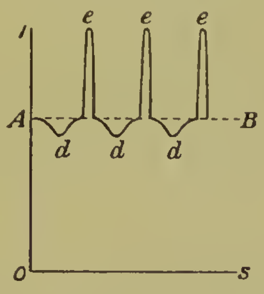


FIG. 20.—Galvano-faradic E. M. F. (Bordier).

where *o A* of the galvanic current represents the amount of the E. M. F. of the galvanic current, and the straight line *A B* parallel to the time line represents the constancy of the E. M. F. The superposed faradic current produces the variations *e, e, e,* and *d, d, d.* The quantity of electricity

is represented by the surface comprised between the line *A*, *d*, *e*, *d*, &c., and the time line *o*, *s*, and is evidently much greater than if the faradic current alone were running.

E. M. F. of constant current dynamo.

A constant current dynamo produces an E. M. F. represented in Fig. 21, where *A B* the line of E. M. F. is parallel to

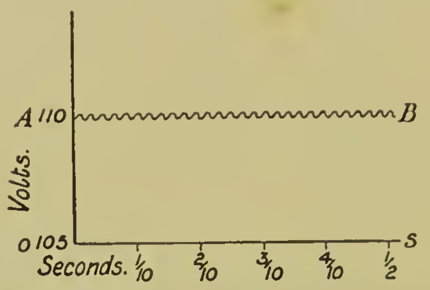


FIG. 21.—E. M. F. of constant current dynamos.

the base line as in the galvanic current, but instead of being a plain line it is a fine wavy line, each little wave representing the slight variations that occur as the bar in the commutator passes underneath the collecting brush. When, owing to the construction of the machine, these wavelets are very marked the current is called "pulsatory."

"Static" E. M. F.

The static machine gives an E. M. F. of two forms. (1) That of the discharge by sparks. (2) That of the discharge by "souffle." When the terminals of the static machine are brought sufficiently near, a spark leaps between them. This is the result of the disruptive discharge. It is called by Bergonié an instantaneous current, and its E. M. F. is represented by Fig. 22. The time represented by *a*, *c*, varies from

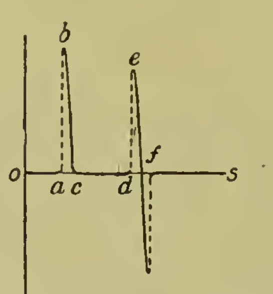


FIG. 22.—Static E. M. F. ("instantaneous")

the twenty millionth to the fifty millionth of a second (Lucas and Cazin). If, however, the nature of the discharge be

altered, *e. g.* by the use of metallic points, there will no longer be a sudden noisy discharge by sparks, but a low hiss, the electric "souffle." It is disruptive, but takes a much longer time than the instantaneous discharge of the spark. In this case the point communicates electricity to the particles of air in its vicinity, and the latter are therefore attracted to the nearest object, for instance the body of a patient, and so there is an actual current of moving electrified particles, a wind or "souffle,"—the "electric breeze."

"High frequency" E. M. F.

A current whose periodicity is very frequent say, 150,000 to a million a second is called a current "of high frequency." These are obtained by particular methods of discharging a condenser. It is not an intermittent discharge, as the instantaneous discharge we have just considered, but its form is that of an undulatory current (Fig. 23). The oscillations take

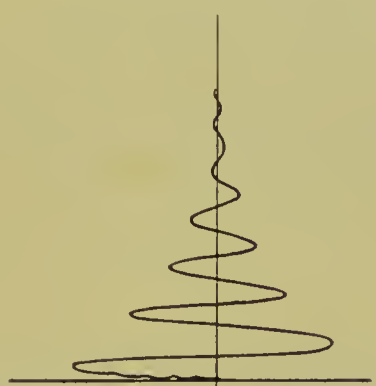


FIG. 23.—Undulating E. M. F. obtained by particular methods of discharging a condenser.

the same time, and the amplitude decreases in a geometrical ratio. Oscillations of an analogous kind may be seen in a bent tube into which water is suddenly allowed to return; a hydrostatic equilibrium does not become established until a series of such oscillations have occurred. But in the condenser discharge the number of oscillations may be a hundred million a second before electrical equilibrium is established.

CHAPTER V

Magnetism. The Induction Coil

Magnetism.

Although, so far as is at present known, magnetism has from a physiological point of view, no influence on the living body, the manifest relationship between magnetism and electricity makes it desirable that certain first principles should receive attention. The magnetic condition can be produced by permanent magnets, or by electric currents. The magnetisation of a substance depends upon the direction and arrangement of its particles. It is assumed that the magnetic flux issues from the north pole of the magnet, and after traversing the region outside, it re-enters at the opposite pole, and passing through the magnet completes the circuit (Fig. 24). The lines of flux, as in the

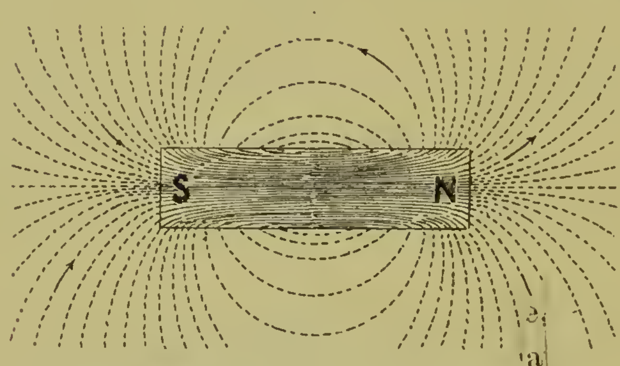


Fig. 24.—Magnet and its lines of magnetic flux.

voltaic and electrostatic circuit, meet with resistance depending upon the nature of the substance they traverse; and the opposite of that resistance is known as "magnetic permeability."* When an electric current passes through a con-

* The magnetic permeability of iron is from 320 to 1200 times that of air.

ductor, *e.g.* through a wire, that conductor temporarily acquires magnetic properties, and magnetic flux surrounds it in concentric circles. Such circles can be made visible by means of iron filings sprinkled over a card pierced by a wire carrying a current (Fig. 25).

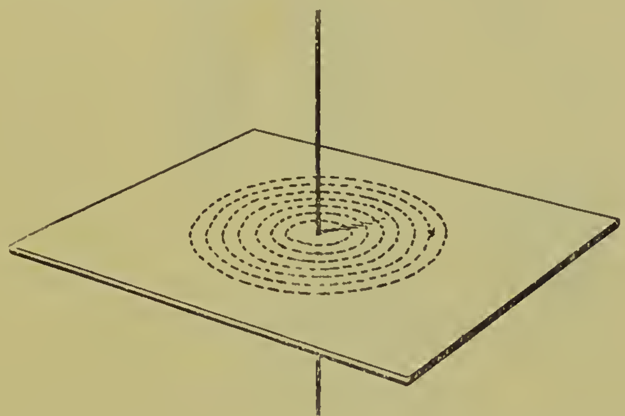


FIG. 25.—Circular lines of magnetic flux surrounding a wire through which a current is passing.

Induction.

If a wire through which a current is passing be in the form of a helix or coil, and a bar of iron be pushed into its interior, the circular lines of force (magnetic flux) will run through the iron and magnetise it, the movement of electricity thus producing magnetism (Fig. 26). The converse also occurs

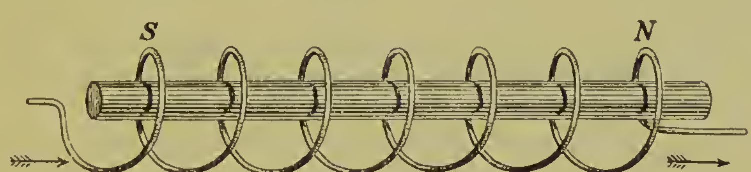


FIG. 26.—The movement of electricity produces magnetism, and the movement of a magnet produces an electric current.

magnetism produces electricity; thus, a magnet pushed into a closed helix will produce an electric current in the helix. This is induction of E. M. F. by magnetism. When a current is sent through one of two coils placed near each other, the one through which the current is passing exercises an inductive effect on the other, *i. e.* the passage of the current through A ("the primary") produces a magnetic flux, part of

which passes through B ("the secondary"), and an E. M. F. is set up in each turn of B. This is "mutual induction" (Fig. 27). But it is only during *alteration* of the current in A, *i. e.* when it

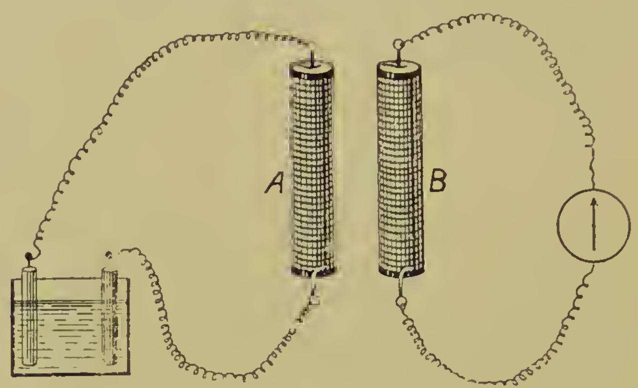


FIG. 27.—Mutual induction.

is being made, or broken, or increased, or diminished, that this mutual induction occurs. At the moment of closing the battery current an inverse induction current arises in the secondary coil, whilst at the moment of opening the battery current, a *direct* current is produced in the secondary, *i. e.* the current in the secondary is then in the same direction as the battery current, and strengthening it. The direction of the current is expressed by Lenz's law, which states that the induced current always has a direction opposite to the cause which produces it.

The distinction between electro-magnetic and magneto-electric induction is brought out by Figs. 28 and 29. A is the inducing or primary coil, the coil through which the cell current passes; B is the coil in which the current is induced, the secondary coil. The terminals of the primary coil being connected to a voltaic cell make the coil an electro-magnet. The magnetic flux thus produced passes through B, thereby inducing an E. M. F.; the current going in one direction on making, in another direction on breaking. In Fig. 29 the motion of the permanent magnet, on being thrust into the coil, produces, as would be shown by the galvanometer, a current in one direction, and when the magnet is withdrawn

a current in the opposite direction. In Fig. 29 we are doing with a permanent magnet what we do in Fig. 28 with a magnet produced by an electric current.*

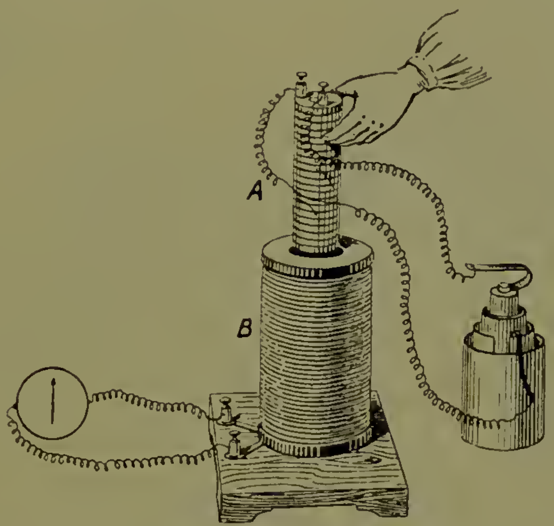


Fig. 28.—Electro-magnetic induction.

It has been shown how a coil through which a current is passing may influence another coil by mutual induction; but Self-induction.

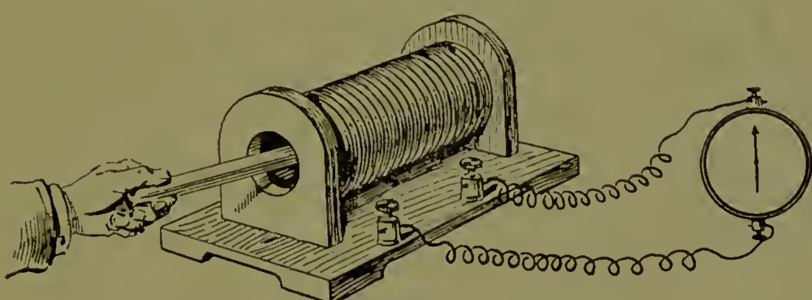


Fig. 29.—Magneto-electric induction.

it would also influence itself. This is "self-induction." That such must occur will be readily seen when it is remembered that during the growth of a current in a circuit there is an increasing number of lines of magnetic flux passing through it, and therefore an induced E. M. F. This E. M. F., which retards the rise and fall of the current, being due to the lines

* There is a form of magne [illegible] or which was well known in medical practice many years ag [illegible] manent horseshoe magnet, near whose poles two coils of fi [illegible] means of multiplying gear. It is seldom seen now.

of force of the current, is called the E. M. F. of self-induction, and explains what is known as the *extra current*. This extra current appears in the form of the spark at break, and is due to the self-induction of the circuit; extra current does not appear at make, because the induced current in the primary is then opposed to that of the inducing current; a counter E. M. F. is thereby produced, retarding the development of the inducing current. At break the induced current is direct, and so *helps* the inducing current, and tends to keep up the strength of the inducing current as that current is disappearing. It thus appears that the effect of self-induction is always to "oppose the change." It acts as an electro-magnetic inertia. If water power be used to drive a wheel, the inertia of the wheel will prevent it from getting into immediate motion. If the water power be stopped, the motion of the wheel will not immediately cease. This is due to inertia.* Similarly, self-induction produces a counter electromotive force, retarding the development of an electric current, and prolonging that current when once set up.

The E. M. F. produced in the secondary has about the same ratio to the E. M. F. in the primary as the number of their respective turns; thus, if a primary coil consist of 50 turns, and the secondary of 2000, the E. M. F. of the secondary will be forty times that of the primary, *i. e.* the E. M. F. will have been "transformed up;" and by reversing the arrangement it can be "transformed down." This is the principle upon which transformers and induction coils are made.

Medical Induction Coil.

The Medical Induction Coil.—The medical induction coil (Fig. 30) is a device for producing E. M. F. by mutual induction between a primary and a secondary circuit. The primary consists of a comparatively short length of coarse wire with few turns, the secondary being of a greater length of finer wire, and more turns.† The secondary is usually wrapped over a

* Houston and Kennell [illegible]

† The primary has be[illegible] of wire, usually No. 22 B. W. G. Resistance about 5 t[illegible] varies between 5 and 50 or more

hollow bobbin, which surrounds the primary. When a current is sent through a primary, and the intensity varied, or the

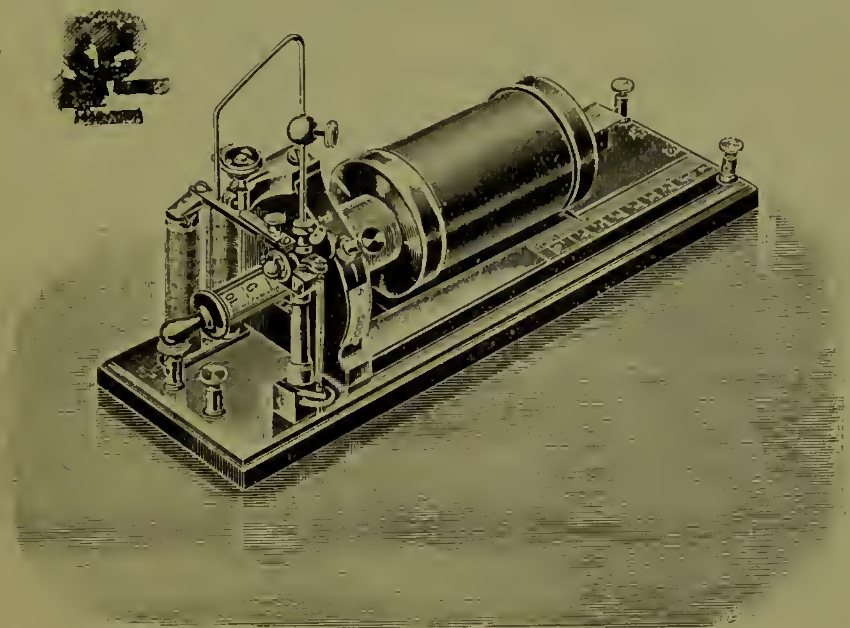


FIG. 30.—A medical induction coil.

current made or broken, an alternating E. M. F. is induced in the secondary. Some device is necessary to make and break the battery current. This usually consists of the automatic vibrator, known as the Neef hammer. Its action depends upon a small electro-magnet, as will be explained in the diagram. The strength of the E. M. F. produced by the coil will depend chiefly on two things—(1) The strength of the current flowing through the primary; (2) The number of turns of wire constituting the secondary (no matter what the size of the wire may be). The "intensity" will, of course, depend upon the E. M. F. generated, and the resistance of the circuit. The resistance of such a circuit is rather a complex one, being made up of the resistance of the coils of

volts, being influenced by the posi[illegible] [illegible]on core, the number of turns of wire, &c.

The secondary may have abo[illegible] [illegible] of thin wire about 36 B. W. G. Resistance varies betw[illegible] [illegible]nd E. M. F. may vary between 10 and 300 volts.

wire, the back or counter E. M. F. (due to self-induction), the R of the connecting wires, and the R of the subject through which the current is passing. For a given primary and secondary circuit we can increase the E. M. F., by increasing the current in the primary, thereby increasing the magnetic flux; or by increasing the frequency with which the current is made or broken.

It thus appears that in the primary coil the inverse inductions, *i. e.* the inductions produced by "make" are practically neutralised and effaced by the battery current;* but the direct induction, that is to say, the current produced at break, being in the same direction as the battery current, acts as a plus to that current. Therefore the current that reaches the patient from the primary wire is not an alternating one; it is a series of impulses all having the same direction.

Fig. 31 is a diagram of the medical induction coil. The battery current passes from the carbon of the cell A to the

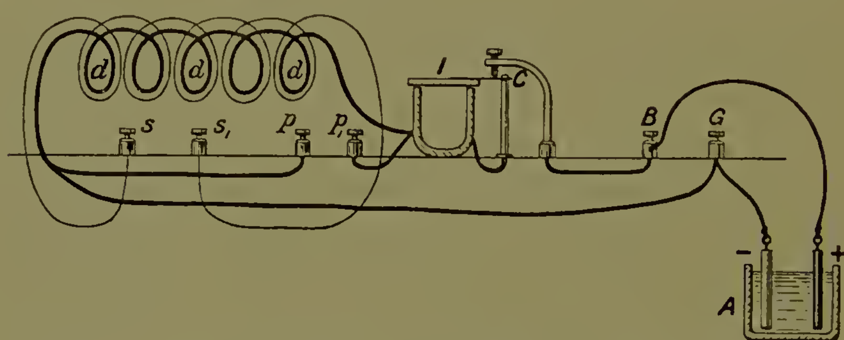


FIG. 31.—Diagram of primary and secondary windings of medical induction coil.

terminal B on the coil. It then passes to the interrupter; and the platinum points of the latter C being in contact, it passes through the primary coil D and back to the battery *viâ* the terminal G. It will be noticed that the primary wire has given a branch to the term... and also one to the terminal P′: and it is evider ... atient be placed between

* The induced curr ... f in the closed circuit formed by the coil and vibrato ... e apparatus (Lewis Jones).

these two terminals he will be between the two ends of the primary coil. The "combined battery" is provided with a suitable switch for thus placing the patient in the circuit of the primary coil. But it is the secondary coil that is chiefly useful in therapeutic electricity.

Automatic vibrator.

In passing through that part of the circuit formed by the small horseshoe coil the current magnetised it, and the result of its having become a magnet is that it attracts the small arm of the interrupter; this separates the platinum points, thereby breaking the battery current, and the horseshoe being no longer a magnet the spring returns to contact, and the whole process is repeated. In short, the automatic vibrator or Wagner hammer (Fig. 32) consists of a magnet

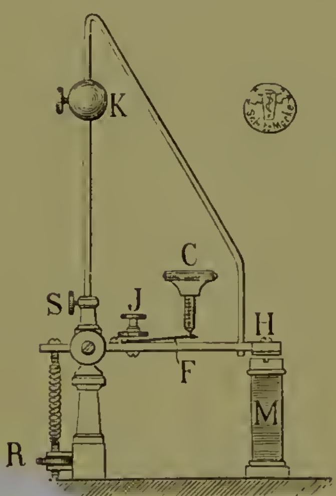


FIG. …matic vibrator or "Wagner hammer."

working against a spring. The spring pressing against the screw point (C) closes the circuit. But as soon as the circuit is closed the small coil becomes a magnet (M) and attracts the hammer (H) (overcoming the force of the spring), and so breaks contact at the screw point. The circuit being broken the small coil ceases to be a magnet, and the hammer springs back to contact, again closing the circuit, again magnetising the coil, and so automatically making and breaking circuit, that is to say, fulfilling the conditions necessary to produce induction. By turning the screw the pressure upon the spring

is altered and the rate of vibration regulated. In order to make the interruptions slower the hammer can be lengthened with a bar on which an aluminium ball can be raised or lowered.

The "Secondary."

In the secondary circuit there is an induced electro-motive force with the rise of the magnetism, and an opposite E. M. F. with the fall of the magnetism, both of which give rise to currents; and because these currents are in opposite directions the secondary is properly called an alternating current. But the wave type is dis-symmetrical (see Fig. 19), the wave at break being greater than the wave at make.* The *quantity* of electricity, however, is the same, although it passes in a shorter time at break than at make, because owing to the counter E. M. F. of self induction, the current in the primary rises comparatively slowly. Owing also to self-induction there is at *break* an E. M. F. of self-induction, but this is in the *same* direction as the battery current, and strengthens it. The magnetism disappears at break more rapidly than it rises at make; therefore at break the E. M. F. is comparatively great, and the intensity is proportionately strong, but of shorter duration than at make. Consequently the break is the more effective stimulus. It is in view of the preponderating influence of the current at break that it has become customary with medical instrument makers to assign to an alternating current that direction in which intensity [illegible] effects are greatest; hence the signs plus and minus on the secondary coil have reference to the direction of the current at break. The form of the induction coil current is given at p. 38.

Regulation of coil currents.

It is necessary that there should be some means of regulating induction coil currents; and several methods are in use. (*a*) The best of these is the "sledge" arrangement, by which the secondary coil can be gradually pushed over or withdrawn from the primary, the latter being fixed. This

* The curve that represents the primary E. M. F. also represents that of the secondary; only the scale is greater owing to the greater number of turns in the secondary and therefore the greater E. M. F.

increases or diminishes the mutual induction in the two circuits; (*b*) By inserting or withdrawing an intensifying core a similar object can be attained, but this is inferior to the sledge arrangement, although a useful accompaniment thereof; (*c*) a third method of decreasing or increasing the magnetising power is by the "shielding" tube; this also is inferior to the sledge; (*d*) coil currents can be regulated by picking up various lengths of the coil wire by means of a pivoted arm touching studs.

In the average English or German coil the interrupter does not receive sufficient attention. Rapidity of vibration ought to be variable according to the requirement in view, and variable within a much wider range than is obtainable by the adjustment of the screw of the ordinary spring. To obtain a really smooth and uniform action the interrupting arrangement or "contact—break" ought to be actuated from a special source.

Rate of interruption influences physiological effects.

Inasmuch as the physiological and therapeutic effects of coil currents depend largely upon the rate of interruption, it is necessary or at least desirable that the medical induction coil be capable of giving a range of from 60 to several thousand interruptions a minute. A current with very slow rate of alternation will produce contractions isolated and distinct. With a greater frequency, say 5 to 10 a second, the individ[illegible]how a tendency to run into each other. With [illegible]ptions yet more frequent the muscle becomes tetanised. This excitant action increases until a rate of about 60 interruptions a second is reached. Then, if the current be a mild one, this effect begins to decrease at about the same rate, until with very rapid alternations the muscle ceases to respond, and a sedative effect is produced on the sensory nerves; at 120 to 150 a second such a current is no longer felt, yet still it produces a sedative or anæsthetic effect. In other words, under the use of an induction coil current, excitant effects gradually increase up to a certain rapidity of interruption and then steadily diminish. For the higher

rates of vibration (2500 to 50,000 a minute) a motor interrupter is required.

Coil currents are of little avail for producing chemical destruction of tissue, but being a series of rapid "current creations," they have a stimulating power peculiar to themselves. The sedative effect above referred to, that follows rapid interruptions, may be due to a numbing effect on the terminations of the sensory nerves.

CHAPTER VI

"Static" Electricity

The phenomena involved in the production of so-called static electricity, as well as the principles underlying the construction of "Frictional" and "Influence" machines, may, in the first instance, be studied in a familiar electrical device known as the Pith Ball Electroscope. Two pith balls are suspended by a dry silk thread upon a horizontal arm, say an ordinary rest or stand. If a stick of sealing wax be now negatively electrified by friction and brought near one of these balls, that ball will first be attracted to the sealing wax, and after contact repelled (Fig. 33). It is attracted

Electrification.

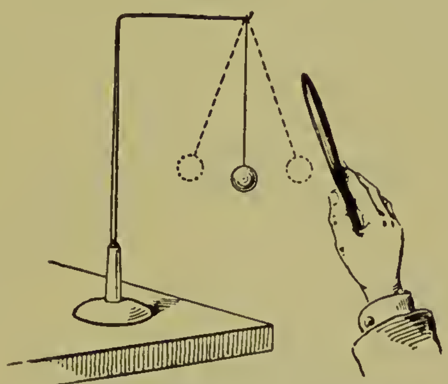


Fig. 33.—Pith Ball Electroscope showing electrostatic attraction and repulsion.

because of the fact that a non-electrified body is attracted by an electrified body; it is repelled because of its having by contact with the sealing wax taken the same charge, and similarly electrified bodies repel each other. If the two balls be now brought near each other they will be mutually attracted because one is charged and the other not. After

contact they will be repelled, because by contact the electrified ball has now imparted a similar charge to the non-electrified ball. Bringing the electrified sealing wax near both balls they will both recede from it, but they will be attracted by a non-electrified body. But suppose now that the silk thread be moistened: on bringing the electrified sealing wax near the ball, attraction will occur as before, but after contact there will be no repulsion, because the silk suspension thread, by being wetted, has now become a conductor and therefore carries off the charge from the pith ball. In other words the pith ball can no longer retain its electric condition; it is no longer insulated; it is connected with that huge conductor the earth, by means of the wet string, the retort stand, and the table. Such experiments therefore have demonstrated—

(1) That bodies may be electrified by friction, a fact known to the Greek philosopher Thales, 600 B.C.; (2) that bodies similarly electrified repel each other; (3) that electrified bodies attract non-electrified bodies;* (4) that an electrified body may communicate its electrification to a non-electrified body by contact; (5) that no body can retain its electrified condition unless separated from earth by insulating material.

FIG. 34.—Electrostatic induction.

Now place a brass rod upon an insulating stand, say upon a well-dried glass bottle (Fig. 34). Attach a pair of pith

* The action is not really between an electrified and a non-electrified body, it is between two electrified bodies; because the electrified body has in the first instance *induced* an opposite electric state in the other body.

balls to each end of the rod, and bring near to the rod the electrified stick of sealing-wax, without allowing the rod and sealing wax to touch; the pith balls will diverge, showing that near proximity to an electrified body *induces* the electric state; the rod is "charged," it has, in fact, been electrified by "*induction*." This induction is the fundamental fact of electrostatic action. Note what has happened. When the negatively electrified sealing-wax was brought near the insulated rod the latter attracted positive electricity to the near end, and repelled negative electricity to the far end.

The electroscope.

In order readily to detect the presence of electrification the electroscope is used. More useful than the pith ball arrangement already noticed is the Gold Leaf Electroscope of Bennet (Fig. 35). Two light strips of gold leaf are

Fig. 35.—Gold Leaf Electroscope.

attached to a metal rod, this passes through the cork of a glass bottle. This bottle answers the double purpose of insulator, and screen to prevent air currents from interfering with the action of the gold leaves. Approach a rubbed glass rod to the knob of the electroscope, the leaves diverge, showing that the body touching the electroscope is in the electric state. But not only does the instrument disclose the fact that a body is electrified, it also gives information of the *kind* of electrification. Proceed thus: First charge the electroscope itself by touching the knob with the rubbed glass rod; the leaves diverge, being positively electrified. When they are thus charged, a positively electrified body brought

near them will cause them to diverge still more. If the body to be tested be negatively electrified, the leaves collapse.

By means of this instrument, and similar simple apparatus, many fundamental facts can be demonstrated. The following are amongst the most important:

(1) Electricity is found on the surface of electrified bodies.*

(2) Electricity tends to accumulate at exposed points or regions of greatest convex curvature.

(3) The electrical effect of a charged body is greater the less the distance from another body.†

(4) Electrical charge can be measured by the mechanical force exhibited between two bodies electrically charged.‡ The instrument by which this is measured is known as an electrometer.

Three words, *charge, potential,* and *capacity,* are constantly mentioned in connection with this subject. Their relationship is as follows:

The potential (difference of electric level) of any conductor is proportional to the charge.

"Capacity" is the charge at unit potential; therefore the ratio of charge to potential is the measurement of capacity. Thus, if C is the capacity, Q the charge, and V the potential, $Q = CV$. The potential varies inversely as the capacity.

The static machine.

A static machine is an electrical and mechanical device for producing and storing such electrical effects as are produced by the friction between the sealing wax and the silk in our first experiment. We must consider the "frictional machine," and the "influence machine."

The frictional machine.

A frictional electric machine consists of a plate or cylinder, usually of glass, which by its rotation rubs against a rubber

* The law is as follows: "In an electrified system electricity is found only on the outer surface of conductors, whether solid or hollow, provided that in the latter case no insulated charges are within it."

† The law being that "the force between two small charged bodies is directly as the product of the charges and inversely as the square of the distance between them."

‡ For further information on this point read Coulomb's "Torsion Balance" in standard electrical books.

of chamois skin or other suitable material, covered or not by an amalgam of mercury and tin. Both rubber and rubbed acquire the electric state (potential). An insulated conductor (the "prime conductor") is furnished with a comb of metal points, which become charged under the inductive influence of the glass surface. A smaller conductor connected with the rubber and not insulated takes the opposite negative charge. A difference of potential is now established between the two conductors which can be continued and increased by the action of the machine. Charges can thus be accumulated capable of producing sparks across a more or less considerable air gap. It is found that an E. M. F. of about 80,000 volts will produce a one-inch spark between two slightly convex surfaces.* When such an E. M. F. rises high enough to discharge across an air gap, it suddenly falls to a more or less variable minimum, again recovers itself and again discharges, and continues to do so whilst the conditions are kept up. Such an E. M. F. is represented in Fig. 22, p. 34.

The "Electrostatic field."

Frictional machines have been found uncertain and unsatisfactory in their action, owing chiefly to hygrometic conditions, and are now replaced by the "Influence machine." To understand the principle and construction of the influence machine it is necessary, besides keeping in mind the foregoing points, to consider a little further what occurs in the space surrounding an electrically charged body, in other words, in the electrostatic field, that is, the region across which electrostatic induction is taking place. Suppose a metal sphere to be charged by contact with a rubbed glass rod. Such a charge is usually regarded as situated on the surface of the charged body. It is more correct to consider the charge as situated in the ether surrounding the metallic sphere. The sphere provides a surface to whose atoms are attached the hypothetical lines of electrostatic force which unite all bodies, and

* Between *points* a smaller E. M. F. is required. The following estimate has been made:

$$\frac{0\cdot18 \text{ mm.}}{1{,}000 \text{ volts}} \qquad \frac{5 \text{ mm.}}{5{,}000} \qquad \frac{18\cdot8 \text{ mm.}}{15{,}000}$$

are stretched when bodies are electrified, *i.e.* along these lines a state of stress exists owing to the elastic resiliency of the æther (see Fig. 1); in other words, these lines have always a tendency to shorten; so that the statement with which this chapter began, viz. that positively and negatively electrified bodies tend to attract each other, might be more accurately stated as follows: positively and negatively electrified bodies being connected by stretched lines of electrostatic force have always a tendency to come together by reason of the contraction and shortening due to the elasticity of their connecting lines. The æther filled up with these lines constitutes the electrostatic field. Now if this field be further explored by introducing into it a conductor, as in Fig. 36, what will

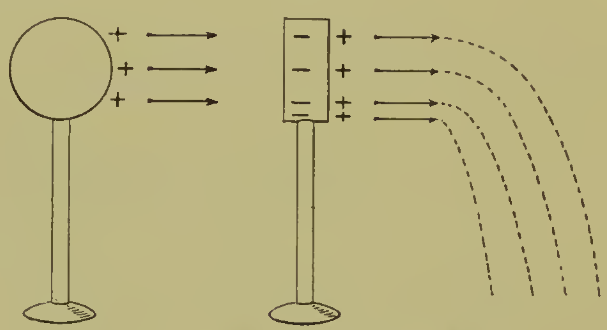


Fig. 36.—The "electrostatic field."

happen? The conductor relieves from electrostatic strain the ether which it displaces. The lines of electrostatic force connected at one end with the charged sphere terminate with an opposite charge on the conductor which has been thrust into the electrostatic field. From the opposite side of the conductor there start other lines of electrostatic force, having a positive sign and ending again with a negative sign on matter somewhere. The appearance of positive and negative charges on the opposite sides of a conductor thrust into an electrostatic field is, as already stated, known as electrostatic induction.

The Electrophorus.

Influence machines are constructed in accordance with these laws of electrostatic induction. In its simplest form an influence machine is represented by the electrophorus (Fig. 37);

A is a disc or plate of sealing-wax, resin, or vulcanite; B is a flat metallic disc fitted with an insulating handle C; A has

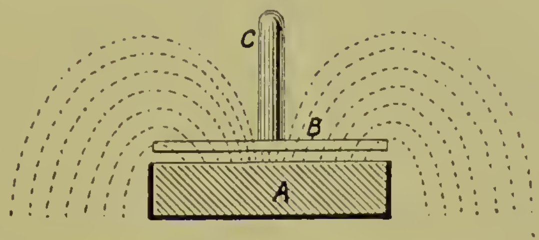


FIG. 37.—The charged electrophorus.

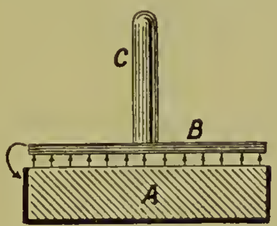


FIG. 38.—The electrophorus, a ground connection having been made.

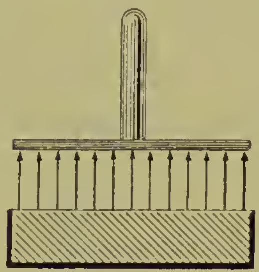


FIG. 39.—The electrophorus, the cover having been raised and the electrostatic circuit lengthened.

been rubbed with a cat's skin, and has become negatively charged. The metal cover has been placed on the electrified disc, and the electrostatic circuit (the electrostatic field) is represented by the arrows. But touch the metal cover with the finger, in other words connect the cover with the ground, now the lines of disturbance of electrical equilibrium exist only between the electrified disc and the metal cover (Fig. 38). There are no lines of electrostatic stress between the cover and the ground, because the cover cannot retain its charge owing to being connected with earth, and having therefore assumed the potential of the earth. The length of the electrostatic circuit has in fact been shortened and strengthened, *i. e.* the distance between the cover and the plate is the smallest possible, therefore induction is the greatest possible. Remove the ground connection and lift the cover; the electrostatic circuit is again drawn out or lengthened (Fig. 39), and a charge is left upon the disc as well as upon the cover; the

latter being positive, the disc negative. This cover represents the collector of an influence machine, and a discharge can be produced from it. The above manœuvre can be repeated, and a series of discharges produced, as long as the electrification of the disc is kept up. This is what the influence machine does. The influence machine is a continuous electrophorus.

Wimshurst influence machine.

Fig. 40 shows a Wimshurst machine. Two or any greater

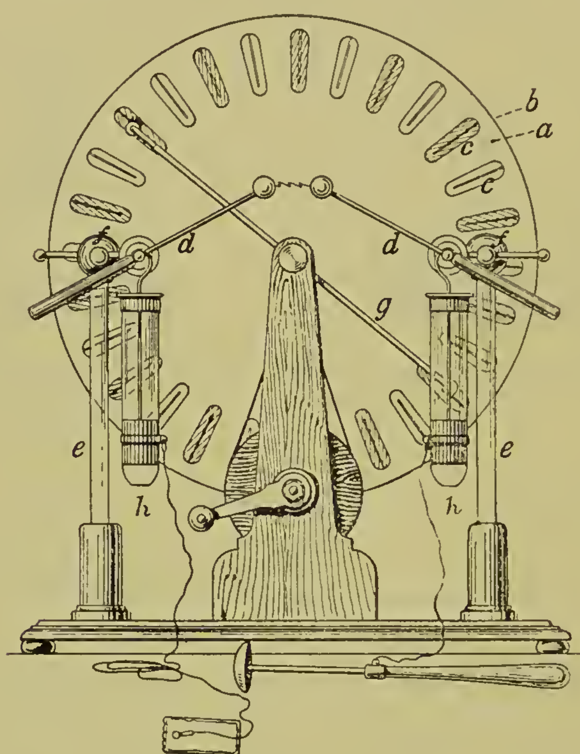


FIG. 40.—Diagram of influence machine with condensers.

number of vertical glass or ebonite discs or plates *a* and *b* are placed rather less than an inch apart, and revolve in opposite directions. Each plate carries several strips of sheet metal, *c c c* (sectors or carriers) which are fixed to the plates radially at intervals. The collectors *f f* are metal combs which closely embrace the discs. These collectors, one charged positively, the other negatively, are attached to large glass or ebonite supports, *e e*, and are in metallic connection with the terminals of the machine, *d d*. In front a metal rod known as

"the neutralising rod, *g*" is fixed diagonally at an angle of 45 to the horizon. There is another similar rod, approximately at right angles to the front one, fixed at the back of the other plate. These neutralising rods carry a metallic brush at each end, so as to rub against the metal sector of the plate. By this means two sectors situated in the same diameter on each plate, are brought into metallic connection at each revolution of the disc.

"To understand the action of the machine, suppose the conductors to be at different potentials and compare the conditions of any two diametrically opposite strips just before they touch the neutralising rod. Evidently they also will be at different potentials, because of their positions relatively to the conductor. Hence there will be a transference of charge from one to the other. On passing beyond the touch of the neutralising rod the strips become disconnected. The one which at first was the higher potential carries a small negative charge on towards the main conductor of lower potential, while the other strip, with its positive charge, moves on towards the main conductor of higher potential. Now exactly the same thing is going on on the other glass plate only in a somewhat reversed manner. . . . .

"It is therefore evident that the neutralising rod is always reducing to the same potential two strips originally at different potentials. When the machine is working briskly there is a constant stream of positive electricity along the neutralising rods on to the travelling strips, and thence across the air spaces to the one main conductor, and of course the constant stream of negative electricity in the other direction." (KNOTT.)

Electric breeze.

We have seen that electricity tends to accumulate at points or convex surfaces. Thus, on the terminals of an electric machine the charge is so dense that it tends to dissipate into the air. The air in the immediate vicinity of a charged point thus itself becomes powerfully charged, and is repelled from the point, carrying with it a charge. This is the "electric breeze" or "souffle," and is often made use of for therapeutic purposes.

Atmospheric electricity.

Induction effects of exactly the same nature as those just described may be produced in the human body. Insulate a chair by placing it on glass supports, *e. g.* on tumblers, place

a person on the chair with one of his hands over a positively charged electroscope, and the other near a negatively charged rod. The leaves diverge, showing the induced positive charge in the hand nearest the electroscope. From this experiment it is not difficult to understand how the living organism may be influenced by the electric state of the atmosphere. When a heavy thunder-cloud, charged say with positive electricity, hangs over the earth, a charge of an opposite kind is induced on the earth immediately beneath; and a man standing on the earth is at the earth's potential. When the lightning flash occurs electrical equilibrium is restored, and earth and cloud for the moment have the same potential. There is, so to speak, an inrush of positive electricity upon the negatively charged earth, and this sudden change of electrical condition is often felt as a shock by persons at some distance. It is known as the "return shock." Even in ordinary weather there is a difference of potential between the air and the earth. In fine weather the potential of the air is usually positive to the earth, but sudden changes in distribution occur, and there can be little doubt that our bodies are in some way influenced thereby.* Indeed, whatever its environment, the human body is under the influence of atmospheric electricity. We live, so to speak, in an electrostatic bath. The phenomena of the latter are identical with those of atmospheric electricity. There is no difference in their nature between the spark of the static machine and forked lightning. One is disruptive discharge between the terminals of the machine, the other is disruptive discharge between cloud and earth, or cloud and cloud. Even in their audible accompaniments they only differ in extent. The character and intensity of the thunder, whether a "clap" or "hiss" or "crackle," depends upon the

* It has been suggested that, inasmuch as the neurasthenic, the rheumatic, the gouty, and persons suffering from spinal cord disease are better on a clear day than on a cloudy one, they ought to be treated by negative electrification. The matter, however, does not seem to be quite so simple as this; although the electric state of the air may eventually prove to be the key to electrostatic treatment.

nature and intensity of the discharge. The rolling and reverberation that follow thunder come under a different category; the sounds in this case are echoes from clouds of different densities (Knott). The thunder-cloud is, perhaps, "charged" by a process similar to that which charges the frictional machine. The rubbing of the glass and the friction that may occur between masses of moisture-laden air may be processes not essentially different. It is known that a jet of steam passing from a boiler through a wooden nozzle produces electricity. This is due to the friction of the particles of condensed water.

Condensers.—"The capacity of a conductor is increased when it is placed near a conductor electrified with the opposite kind of charge." The action of all forms of condenser depend upon this fact. Sheets of tinfoil separated by sheets of paraffin paper act as efficient condensers; but the most important form of condenser is the Leyden jar (Fig. 40, *h h*). This is a glass jar with an inner and outer coating of tinfoil up to a certain height; a brass wire carrying a knob at its upper end, and having a brass chain attached to its lower end, passes through the top of the jar, the chain falling on the inner coating. When, by holding the knob to the prime conductor of the electrical machine the inner coating is charged, it acts inductively on the outer coating, across the glass, attracting a negative charge to the glass side of the outer coating, and a positive charge to the outside of the outer coating, and thence through a chain or other conductor to earth. If the two coatings be connected by a conductor, the two opposite charges "attract one another," and the jar is discharged. If by touching the outer coating with one hand, and the knob attached to the inner coating with the other hand, the body offers a path to the current a severe shock is felt. Such shocks are not, or at least ought not, to be much used in therapeutic electricity. Condensers.

Static electricity applied to the body for therapeutic purposes is known as Franklinisation. For one form of its E.M.F. see p. 34. The apparatus required is (1) a static Franklinisation.

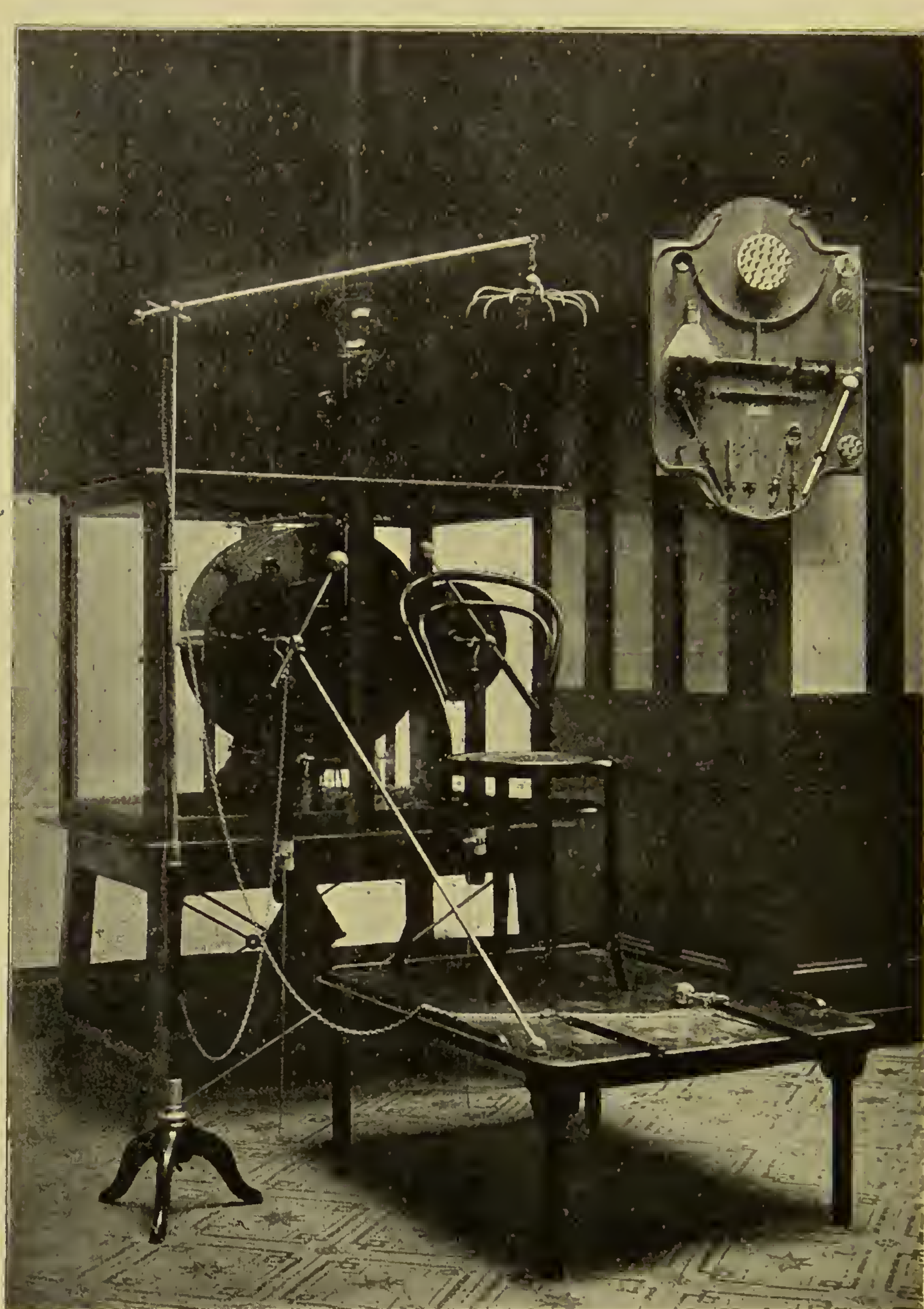


FIG. 41.—Equipment for "static" treatment.

machine of, say, four to eight plates, or more; (2) an insulating stool, *i.e.* a small platform with glass legs twelve inches in length (Fig. 41); (3) a chair either of metal or covered with gold leaf to stand upon the insulating stool. This metallic coating diminishes resistance, and increases the quantity and pressure. (4) Exciters (Fig. 43). Sparks can be applied either directly to the body or indirectly. For the

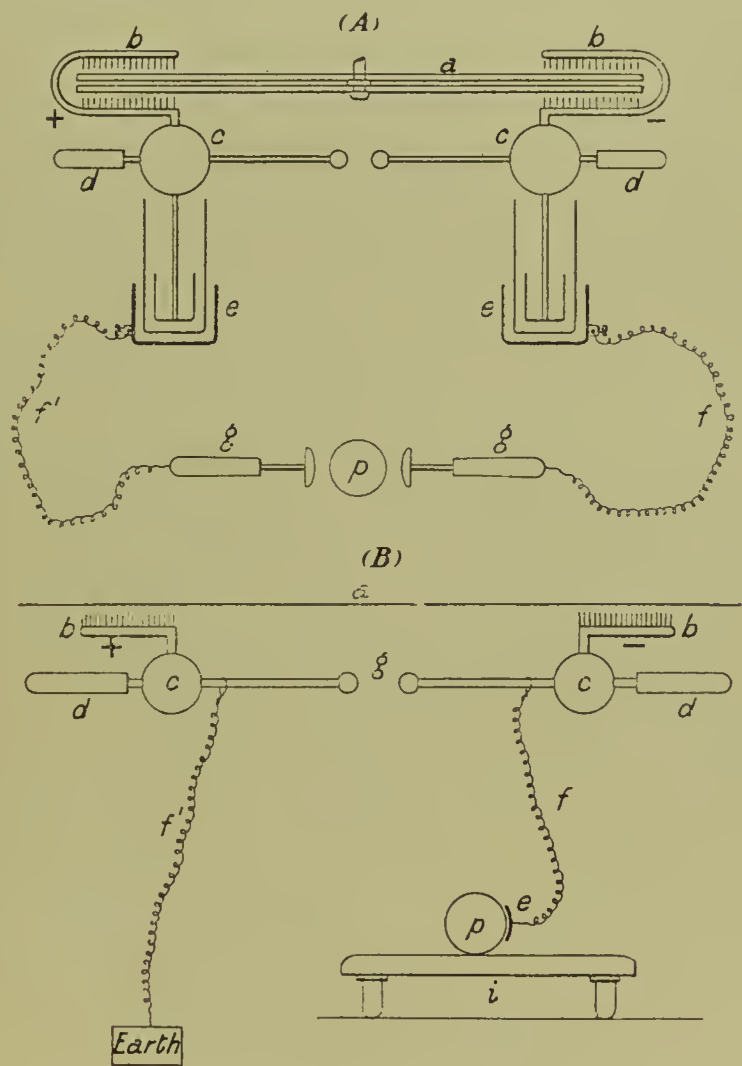


FIG. 42.

former, a brass or wooden knob is used with an insulating handle of glass or ebonite. To this handle is fixed a chain which passes through a ring carried by a second insulating handle, which the operator holds in his hand, at the same time

holding in his other hand the knob by its insulating handle. The end of the chain is attached to one pole of the machine or to earth. The size of the knob, and the speed of the machine, and the distance from the body, will regulate the spark.* For indirect application the exciter of Roumillac is useful. It measures exactly the length of the spark, and by permitting the knobs to touch can be used also for direct excitation. The equipment for static treatment is shown in Fig. 41.

Static induced current.

To produce powerful and painless muscular contraction the "static induced current" or "current of Morton" will be found the most serviceable. It is the product of the static machine with condensers (Figs. 40, 41, and 42 A). The inner coating of the Leyden jars is connected with the discharging rods, the latter being separated by a small spark gap. If, now, a conducting cord attached to the outer coating of each Leyden jar be held in each hand, it is evident that such an arrangement gives two circuits; one includes the discharging rods, the spark gap, and the inner casing of the jars; in the other circuit there is the patient's body, the conducting cords, and the outer coating of the Leyden jars (Fig. 42 A). This current can be applied to the body by ordinary electrodes, as in the case of continuous or induced currents (Fig. 42 A).

Another development in static currents has lately been introduced by Dr. Morton. It is diagrammatically shown in Fig. 42 B. In this disposition of the apparatus it will be seen that the patient is not directly included in the sparking-circuit of the machine, but is indirectly connected to that part of it which "constitutes one side of a spark gap whose other side is preferably connected to the ground." When sparks are made to pass at *g* painless muscular contractions are produced. Any ordinary moist electrode may be used, or metallic plates. They may be attached to the patient, or if held in the operator's hand they must have insulated handles. This method is found to be useful in rheumatism, lumbago, and other condi-

* The "Cleaves static controller" effectually regulates the strength of static applications.

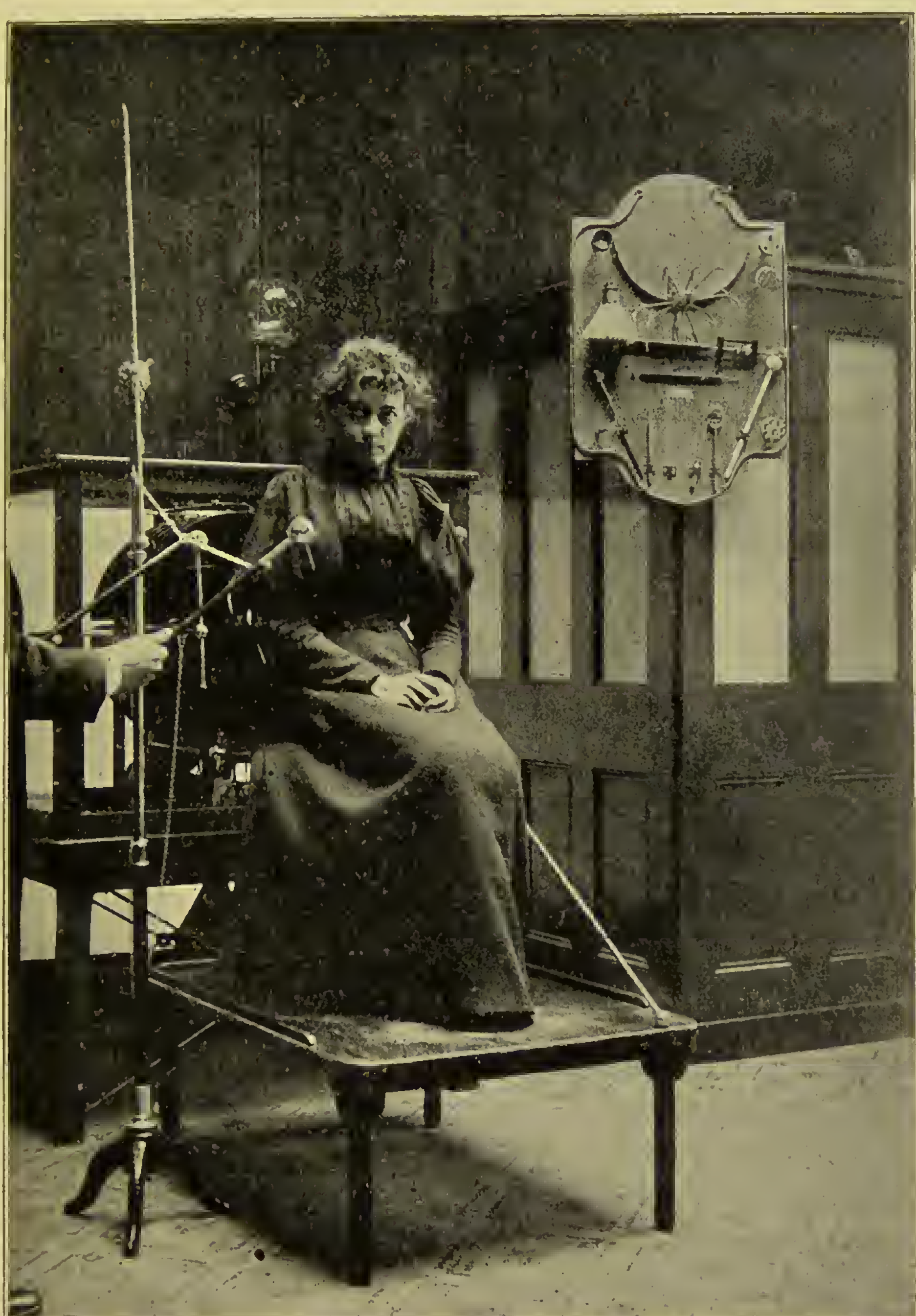


FIG. 43.—"The Universal Discharger."—Method of localising souffle, sparks, and other forms of discharge.

tions; and Dr. Morton gives eighty cases of sciatica and brachial neuritis and neuralgia in which it has been successfully employed. It is applied in the "most acute cases and with immediate relief from pain."

Electric breeze.

The breeze can be applied either with the patient placed upon the insulating platform, or sitting uninsulated on an ordinary chair. For practical therapeutic purposes it is not of the very highest importance to distinguish between the two poles of the machine, but a ready means of doing so when required is to place a lighted candle near one of the poles; that pole from which the flame is blown away is the positive.

There are several methods of "Franklinisation."

Methods of Franklinisation.

(1) *Sparks.*—When the brass knob, with its chain falling to earth, is brought near the patient's skin sparks are produced (Fig. 43). Besides the sense of prick or slight shock, there are produced motor and vaso-motor phenomena. The latter show themselves by a pallor, followed by redness, and accompanied by a rise in the temperature of the skin. In certain pathological conditions, and notably in exophthalmic goitre, the vaso-motor effects are so marked as to have given the name of "electric dermographism" to the figures that can be traced on the skin by means of the sparks (Bordier). The motor effects appear in a muscular contraction, more suddenly developed by the negative pole spark than by the positive. The extent of the muscular contraction is proportional to the square of the length of the spark, and also proportional to the diameter of the exciter (Bordier).

(2) *Friction.*—A spherical or roller exciter is passed over the clothes the patient is wearing, and a multitude of small sparks result, whose length depends on the thickness of the clothes. Thus, there is produced a local excitant action as well as certain reflex effects, but the general effect is usually sedative.

(3) *Electric breeze.*—The negative souffle is stronger than the positive. Useful in neurasthenic pains and certain forms of headache and as a localised application in eczema and

eczematous affections. The negative souffle produces a greater lowering of local cutaneous temperature than the positive.

(4) *The electrostatic bath.*—The patient is placed upon the insulating stool, and the latter being connected with one pole of the machine, the patient acquires the potential of that pole. His sensations are almost *nil,* but he is traversed by a current of high tension electricity, which escapes from every salient point of his body. The word "static" is not therefore quite an accurate designation for "Franklinic" electricity.

Effects upon the body.

The physiological effects of the "static bath" are as follows: (1) The frequency of the pulse and arterial tension are both increased; (2) Central temperature slightly increased ($\frac{3}{10}$ of a degree Vigouroux); (3) Muscular power, as shown by the dynamometer, is at first increased, but after too long a series of séances is diminished; (4) Respiratory combustions are increased, an effect perhaps due to the ozone; (5) Sudoriparous glands become more active; (6) The ratio of urea to the total nitrogen is augmented; that is to say, a greater proportion of nitrogenous compounds is eliminated in the form of urea. These results do not follow the first two applications; on the other hand, if the applications are too frequent, an opposite result ensues; (7) Digestive functions improve and appetite increases. The static bath is sometimes more effective than iron in anæmic conditions; (8) A feeling of calmness and well-being and disposition to sleep follow its use. (9) It acts upon cutaneous and vaso-motor nerves; dry skin becomes moist, and cutaneous circulation becomes active. Whichever pole be used the above effects are obtained (Bordier). But certain writers are of opinion that the positive "bath" has a soothing action and the negative an exciting one.

CHAPTER VII

Currents of Great Frequency and High Potential

These currents were first investigated from the physiological and therapeutic standpoint by d'Arsonval.* They can be obtained by means of a Ruhmhorff coil (Fig. 44) or of alternating light circuits (Fig. 45).

Fig. 45 shows (*a*) at the lowest part of the diagram an alternating current dynamo producing a current of low frequency at 110 volts; (*b*) an ampèremeter; (*c*) a commutator; (*d*) the primary of a transformer; (*e*) a regulator consisting of a simple self-induction coil of about seven turns, with a core by which the apparent R. of the coil can be graduated, and so regulate the energy in the primary of the transformer. The transformer may take ten ampères at 110 volts (1100 watts). This may be said to constitute the first circuit. Following the connections upwards the figure shows the secondary of the transformer (*f*); this constitutes another circuit traversed by a current of very high potential (15,000 volts); this is the dangerous circuit. The transformer ought to be enclosed in a metal receptacle and completely plunged into a mass of paraffin to ensure safety of insulation. Proceeding from the secondary coil of the transformer (*f*) the current reaches the armatures of a condenser (*g*), and thence traverses a spark gap (*h*).† In the third circuit, the circuit of high frequency and no danger, the oscillating discharge passing from the condenser, traverses the solenoid (*i*).

* The terms galvanisation and faradisation seem to have secured a permanent place in the faulty nomenclature of electro-therapeutics; we are now threatened with "d'Arsonvalisation."

† The spark must be "blown" by air or by a magnetic field.

It is this solenoid which furnishes the current of high frequency and high potential for purposes of treatment. Such currents can be produced in the living body by its being placed in a large solenoid, and the latter enables the coil last

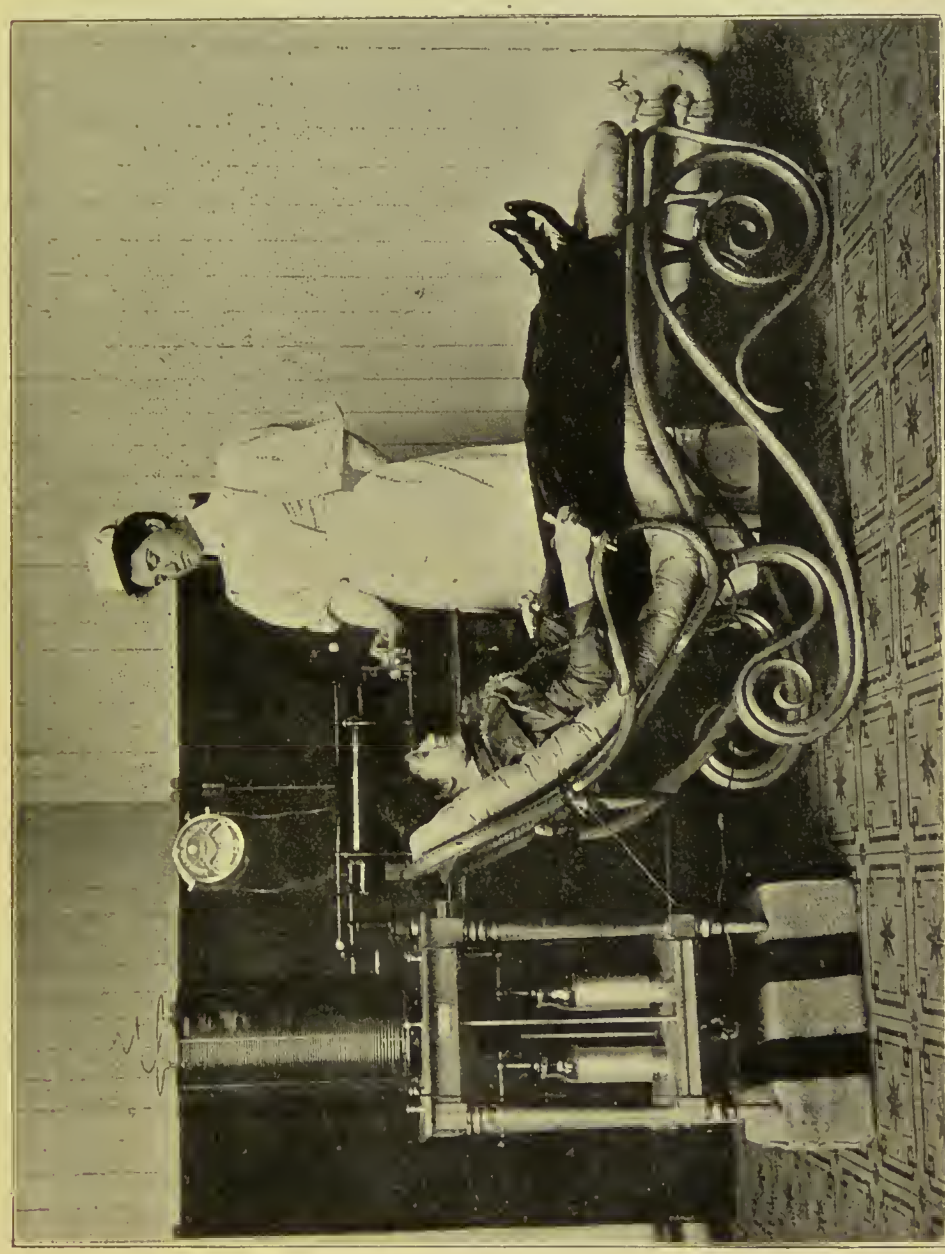


FIG. 44.—High frequency currents—"condensation."

described (*i*) to be dispensed with. This is the method of autoconduction (Fig. 46). Under these conditions sparks can be drawn from the body. A second method is to place

FIG. 44A.—High frequency currents with Wehnelt Interrupter* (Dr. Hedley).

* Installation by Mr. Dean.

the terminals of the solenoid (*i*) in actual communication with the part of the body to be treated by means of suitable elec-

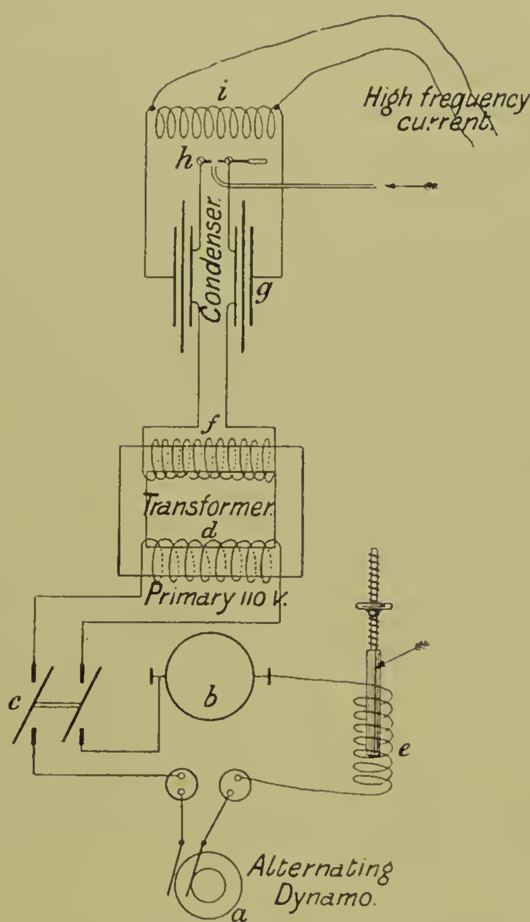


FIG. 45.—Diagram showing high frequency currents obtained from alternating light currents.

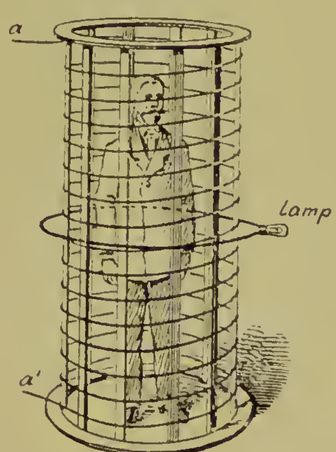


FIG. 46.—Autoconduction.

trodes. If a gap be made in any part of the metallic circuit, each time there is a spark across the gap painless muscular contraction is produced. A third method is the method by "condensation" (Fig. 44). The person under treatment in this case constitutes one armature of a condenser, the other armature being near.* Currents of 300 m.a. may, under this arrangement, pass through the body. For currents of high frequency, intensity is measured by means of a thermometer empirically graduated by measuring with the ampèremeter a current of low frequency. The physiological effects of such currents are found to be as follows:

Physiological and therapeutic effects.

1. Analgesia at the point of entry and exit of the current.
2. A fall of arterial tension.
3. Increased action of the skin.
4. Increase in the respiratory combustions.
5. The virulence of blue pus is attenuated, and after about half an hour's application the bacillus dies. It has further been shown that an active diphtheritic toxine through which such currents are passed loses its toxicity; a result due, perhaps, to the molecular shaking to which the culture is subjected by the passage of a current of such high frequency of alternation.†

In a communication made to the Academy of Sciences, Paris, August, 1897, it is claimed for this current: (1) that it facilitates the elimination of waste products by the kidney; (2) that it increases the activity of the organic combustions; (3) that it tends to bring about a return to the normal ratio between uric acid and urea. Speaking generally, its effect in suitable cases is to improve the general condition, nutrition, and "tone" of the body, to restore appetite, sleep, and digestion, to induce an increasing energy and capacity for work. It has given negative results in neurasthenia, hysteria, and neuritis, but has proved useful in chronic rheumatism, "goutiness," obesity, asthma, anæmia, and diabetes. It is essentially

* A sheet of metal below the cushion of the couch.

† Communication made to the National Society of Physics, 1897.

the current that acts on the nutritive processes and cell life. It further has an action in skin disease similar to that of the static breeze but stronger, especially in superficial diseases of the skin, in superficial ulcers, in syphilides, and in various forms of eczema, psoriasis, and acne, and in affections of the mucous membrane. For this purpose the electrode of Dr. Oudin will be found useful.

CHAPTER VIII

Current from the Main

The Dynamo.

A DYNAMO is a machine which, by means of electro-dynamic induction, enables us to convert *mechanical* energy into electrical energy. The simplest form of dynamo would be constructed by taking a loop of wire A (Fig. 47),

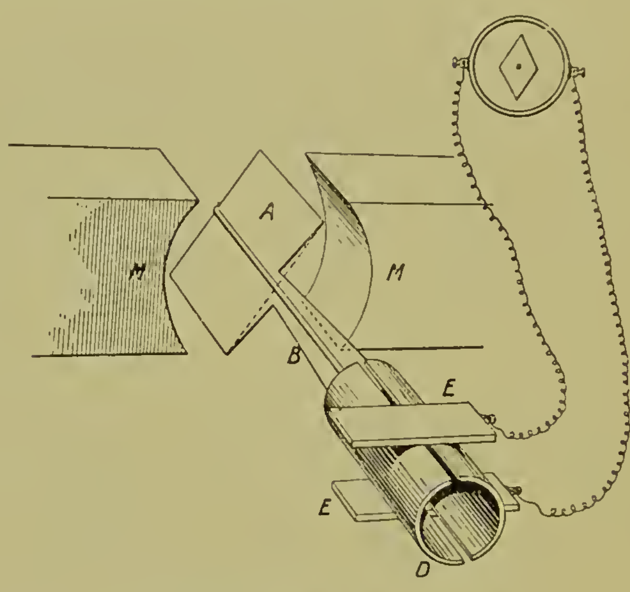


FIG. 47.—Simple form of dynamo.

mounted on a shaft (B), and rotating it between the North and South pole of a magnet (M M). In doing this a current is induced in the loop in one direction as it approaches the horizontal position, and in another as it approaches the vertical position. If we also place upon the shaft two metallic rings, connected to the ends of the loop of wire, and adjust springs or brushes (E E); so as to rest upon the rings we can carry off the current. As the latter flows

first in one direction and then in another, it is an "alternating current." But if, instead of two simple rings, we connect the ends of the wire loop to a split tube (D), we so alter the conditions that instead of an alternating current we produce a "continuous" one, *i. e.* one always travelling in the same direction. We have, in fact, "rectified" or commuted an alternating current into a continuous one. The principal parts of a dynamo-electric machine are the magnets (M M), the armature (A), the commutator (D), and the collecting brushes (E E).

The armature. In a practical dynamo (Fig. 55) the armature, consisting of several coils of wire wound round a ring or hollow cylinder, is made to revolve in the magnetic field comprised between the poles of the magnets, the ends of each of the coils of wire being connected together, and to the insulated segments of the commutator, upon which rest the collecting brushes which carry off the currents thus induced.

The collecting brushes.

The magnets. Now when the armature is revolving rapidly in the magnetic field produced by the magnets the lines of magnetic force are "cut," and differences of potential are generated in the conducting wires, so that when they are connected to a closed circuit the currents produced flow, as already stated, in one direction when the armature passes the North pole, and in another direction when the South pole of the magnet is passed.

The Commutator. To obviate the consequences of this, and to cause the current to flow in one direction only, is the object of the "commutator." The latter is, as already said, divided into segments,

FIG. 48.—The Commutator.

and the brushes are so placed that they are in contact with the respective segments so long as the current flows in

the same direction as the wire coil is revolving, *e. g.* in Fig. 48 when the current is going in one direction the brushes are on (D E), and on (E D) when going in the opposite direction. In this way the current is made to flow in the same direction throughout the circuit. In other words, every dynamo is an alternating current generator, and its E. M. F. may be diagrammatically represented by the curved line in Fig. 18. But by using the commutator we produce a current which flows only in one direction. With one coil on the armature there are two waves per revolution; with a larger number of coils there are a larger number of waves, but the latter would be very small. And if, as in the case of modern central lighting stations, a number of dynamos running at different speeeds, and having commutators of numerous sections, are used in parallel with accumulators of large capacity, the line of E. M. F. is practically straight (Fig. 21). It is such circuits only that are fit for electro-therapeutic use, when continuous current is required. It may be added that when it is desired to increase the potential only, dynamos, like batteries, are connected "in series;" when it is desired to increase the current or ampèrage only, they are connected "in parallel" or "multiple-arc." If an increase of both potential and current is required, the two previous methods may be combined, that is to say, they will be connected in "groups" or "multiple series."

Dangers.

With due precautions electric lighting mains may be used for therapeutic purposes. It is well to ascertain in the first instance that there is no possibility of any sudden interruption in the circuit. The risk of failure of supply and sudden rise in supply pressure need not be seriously considered in the case of English companies. The dangers due to leakage and breakdown of transformers represent practically the whole of the difficulties that have to be contended with. These risks are fully dealt with in 'Current from the Main.'*

* See 'Current from the Main,' W. S. Hedley. Lewis and Co.

Continuous currents.—(1) For their use a reliable "cut-out" should be placed in every therapeutic circuit. The Cunynghame "magnetic cut-out" is the best. Lamps and fuses are not nearly so trustworthy.* Methods of utilising continuous dynamo currents.

(2) The patient should never be "in series" with the rheostat; *i.e.* the patient's circuit should always be a "shunt circuit," on the principle shown in diagram (Fig. 49),

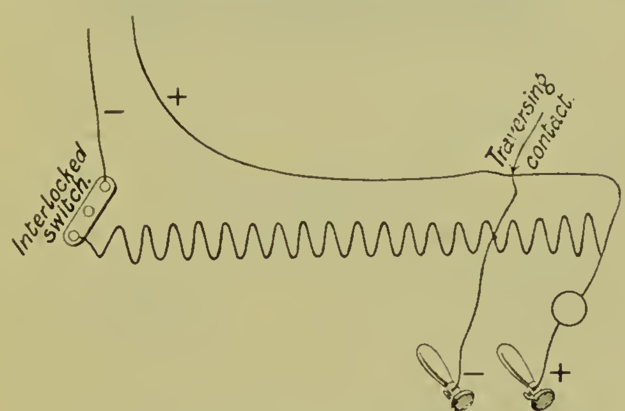


FIG. 49.—The "sliding shunt."

where the traversing contact allows the use of just so much E. M. F. as is required for the purpose in hand.†

In point of pain and some other physiological effects there is undoubtedly a great difference between applying, say 10 m.a. at 100 volts through a resistance placed in series with a patient, and applying 10 m.a. with only just sufficient E. M. F. to overcome the R. of the patient's body; and this will hold good whether the 10 m.a. be obtained from a Leclanché battery or from any other source.‡ Fig. 50 shows an apparatus for this purpose. (1) The R. is not altered step by step but gradually throughout its whole range. (2) The switch and R. are so locked that it is impossible to open or close the main circuit until the potential across the shunt circuit is nil. (3) It has a very wide range. (4) It has an adjustable stop, so that any range from zero to the limit can be obtained.

* 'Current from the Main,' Lewis, London.

† Ibid.

‡ See p. 25 with reference to C^2R law.

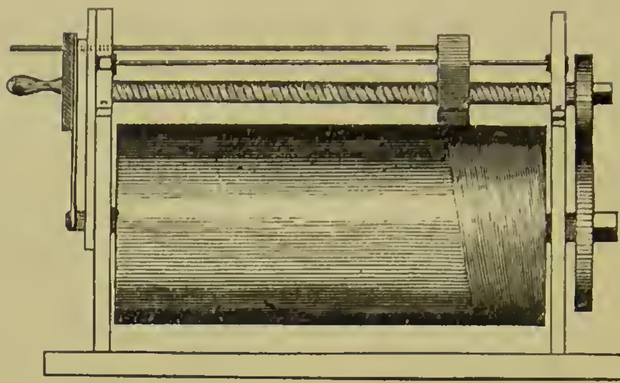


FIG. 50.—Interlocked shunt rheostat (Dr. Hedley).

Fig. 51* shows another very efficient apparatus for the same purpose.

With continuous currents from a "transformed system" it will be well to interpose a motor, and make this drive by belt a small dynamo, which should *not* be fixed on the same metal bed-plate.

For therapeutic purposes there are theoretical but no very serious practical differences between the E. M. F. of a continuous current from a modern English central lighting station and the current from a battery of Leclanché cells, if in using the former the patient be placed in a shunt circuit. Certainly there is no difference in the chemical effects; I have carefully tested the latter point by means of a Gaiffe's coulombmeter with a given current for a given time from these two sources respectively, and I find that within the range of experimental accuracy (within 2 per cent.) the results are the same, *i. e.* from either source equal intensities, as indicated by the galvanometer, will do an equal amount of electrolytic work in a given time.

The Board of Trade Regulations provide that "the pressure of a supply delivered to any consumer shall not exceed 250 volts at any pair of terminals." Thus on the multiple wire system a 500 volt shock is obtainable across the outer mains; and a 500 volt shock could under certain conditions be got

* Schall.

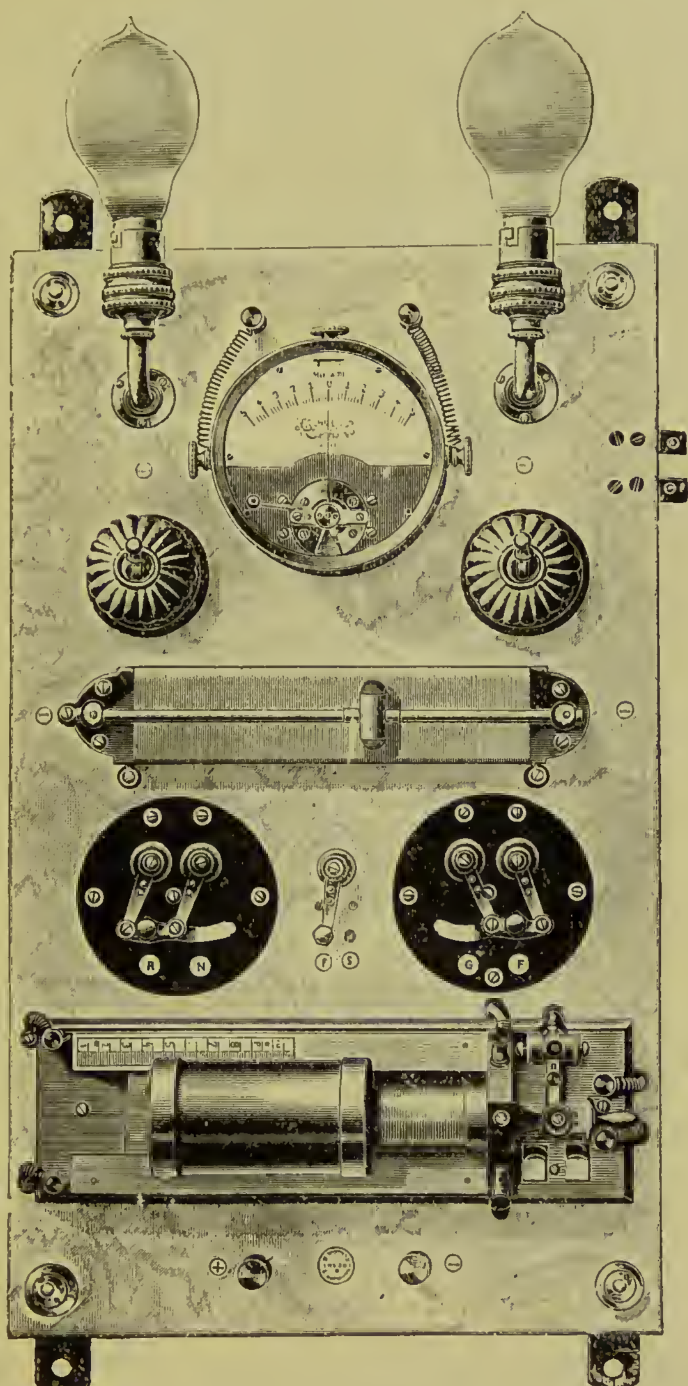


FIG. 51.—Rheostat for using dynamo current for "galvanisation and faradisation."*

from the positive pole to earth. Such accidents ought to be guarded against by placing the patient on the neutral pole,

* Schall.

and effectively insulating him from earth. A very considerable R. is required (between the mains) in the sliding shunt rheostat. This can easily be done by using an 8-candle power or smaller lamp in series with the rheostat, taking care that full incandescence is attained, under working conditions.

Cautery from continuous dynamo currents.

Fig. 52 shows a rheostat for using *continuous* dynamo currents at 100 to 250 volts for cautery purposes. For every

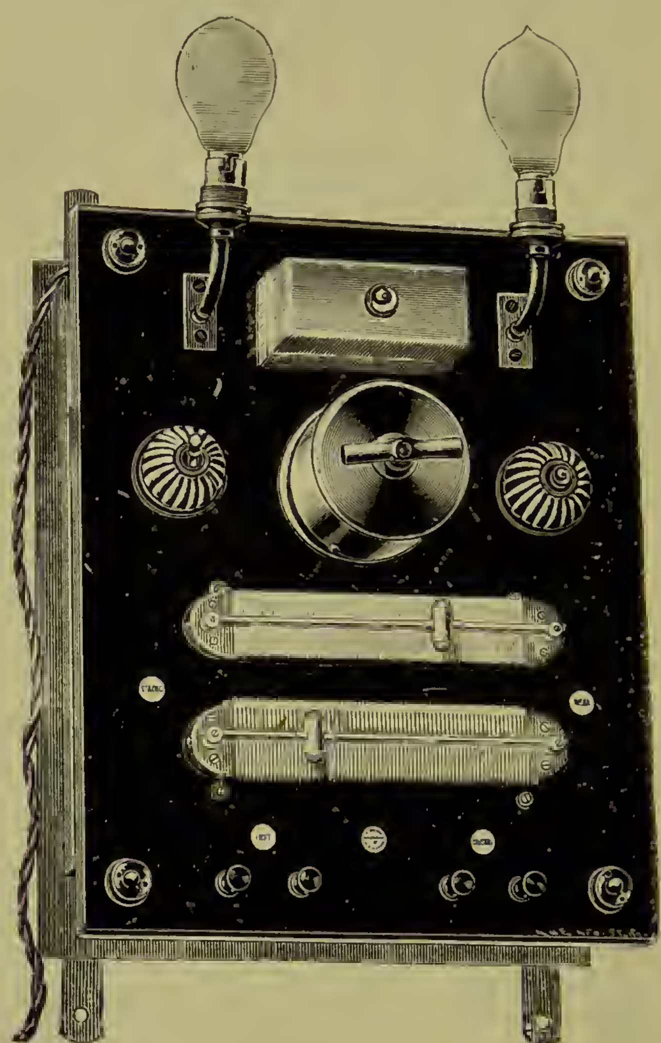


FIG. 52.—Rheostat for using continuous dynamo current for cautery purposes.*

hour it is connected with the main it uses two and a half units of electricity.

Where only continuous current is available it is, as a rule,

* Schall.

better to use it to charge accumulators for cautery and light purposes, instead of using current direct through a rheostat.

For accumulators and how to charge them see p. 16.*

Alternating dynamo currents.—Such currents are easily and safely utilised by placing a substantially made transformer in the circuit. A transformer is, as we have seen, nothing more than an induction apparatus through which an alternating current passes, and in the secondary of which an induced current is obtained whose E. M. F. is of the same form as that of the inducing current; the volts in the secondary being to the volts in the primary in direct proportion to the number of turns of wire. Thus 100 volts may be "transformed down" to six, eight, or any desired number. It is of great consequence that the arrangement permit of just such an amount of voltage being taken from the secondary as is required for the purpose in hand. This can be secured in Gaiffe's "universal transformer" shown in Fig. 53. In this instrument

Method of utilising alternating dynamo currents for direct application, cautery, and light.

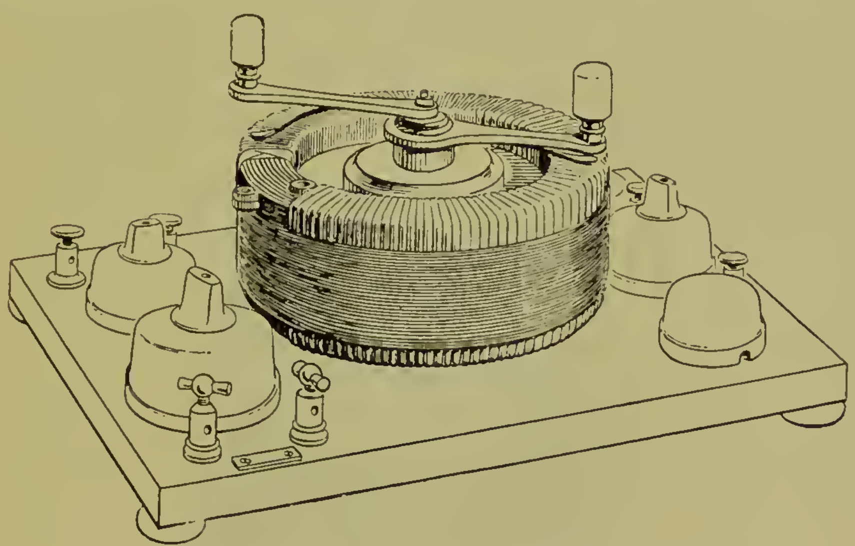


FIG. 53.—Gaiffe's "Universal Transformer."

there is also space available to wind a secondary wire for a surgical lamp; and this can be used at the same time as the cautery. If neither the cautery nor the lamp be used the apparatus will give a current of more or less sinusoidal form

* And appendix.

for direct application to the patient; but in this case neither the cautery nor lamp can be used at the same time.

The cautery for medical purposes may take from 2 to 3 volts and 10 to 30 ampères; surgical lamps 2 to 10 volts and 0·5 to 1·5 ampères. The more powerful lamps or projectors take of course larger currents, but they seldom require more than 16 volts and 2 ampères. For direct treatment of the patient the largest amount of current that can be required is 125 m.a. and 20 volts, and this is the maximum even for the hydroelectric bath. A "Woakes" or a "Miller and Woods" transformer may be used for the same purposes. The first-named instrument has on one bobbin three separate secondary coils, one supplies cautery, the second light, and the third gives current for application to the patient. The "Miller and Woods" is provided with a number of terminals, so that any voltage from 2 volts upwards, and any current up to 20 ampères can be obtained. Every such instrument should be tested with at least the pressure of the primary mains between its primary and secondary windings before being installed for work.

Fig. 54 shows another kind of transformer for using currents from alternators for cautery, and surgical lamps. To

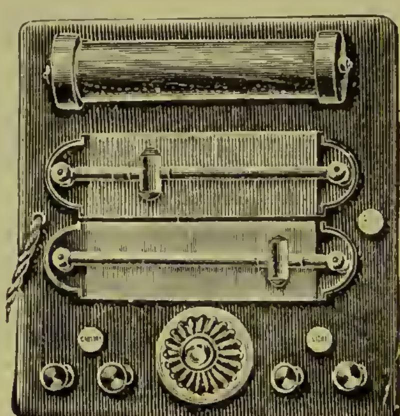


FIG. 54.—Transformer for alternating dynamo currents for cautery and surgical lamps.*

keep a platinum burner alight for one hour this apparatus takes about half a unit of electricity.†

* Schall.

† A Board of Trade unit is 1000 watts (*see* Electrical Units, p. 23).

Currents of a sinusoidal type may easily be obtained, even if the electric lighting circuit be a continuous one, by the use of a small motor driving an alternating current generator. The therapeutic alternator of Kennelly and other instruments of the same type are well known. Even if the supply be an alternating one this arrangement might be preferable to simply using current through a transformer, inasmuch as the E. M. F. and frequency of the useful circuit could thus be accurately controlled.

Putting the foregoing points into technical language for the guidance of instrument makers they may be summed up as follows: The ideal system from an electro-therapeutic point of view would seem to be a direct continuous current supply with a traversing interlocked shunt rheostat, for the purposes of direct application;* together with a motor driven alternator, arrangements for varying speed, field excitation, and the insertion of "capacity," "self-induction," or "resistance," periodically or continuously into the circuit. For light, cautery, and charging accumulators the requirements are adequately met in existing apparatus in trade catalogues. With these arrangements, and with the safety devices previously recommended, any form of current can be obtained with a wide range of electro-motive force and periodicity ("frequency"), and at the same time with an absolute absence of risk. The time ought to be approaching when electricity will be prescribed and administered not only in measured units of intensity, density, and time, but with definite ideas of the shape of the electro-motive force curve, and of the therapeutic indications that a given curve may be expected to fulfil.

Sinusoidal voltaisation.

Under the name of "*sinusoidal voltaisation*," Prof. d'Arsonval has recently introduced the sinusoidal currents into practice. We have seen (Fig. 18) the form of E. M. F. thus produced,—it is of a symmetrical, alternating type. The very smooth and regular variations in the current do not act pain-

* Fig. 51 fulfils the requirements.

fully on the sensory nerves as do the brusque alternations of the coil. There is experimental and clinical evidence to show that without producing muscular contraction these currents have a powerful action on nutrition, and especially on the oxidations. Although often without action on the striated muscles, they nevertheless produce vigorous contractions in the non-striated muscles. In certain painful conditions of the uterus and its appendages a very marked sedative action is obtained (Apostoli). Their power to produce the migration of the ions in the human body has been proved by applications through bath electrodes containing pilocarpine, the frequency being varied from 6 to 120 periods a second, and the E. M. F. being 27 V. The effects of pilocarpine upon the sudoriparous glands appeared *simultaneously* at the two electrodes; this action, well marked with a low frequency, went on decreasing as the frequency increased. Prof. d'Arsonval's dynamo for producing these currents is shown in Fig. 55.

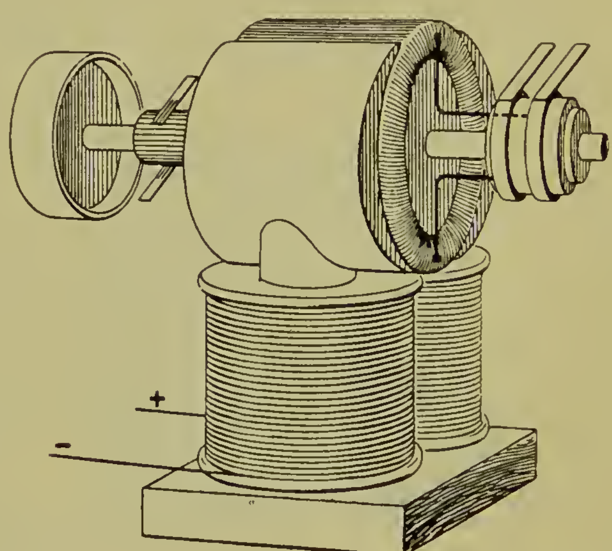


FIG. 55.—D'Arsonval's dynamo for "sinusoidal voltaisation."

Experimenting with a Kennelly alternator run at very high speed, the following points have been recorded.*

* E. W. Scripture, in 'Science.'

Frequency influences sensory and motor effects.

Sensory effects depend upon the frequency :

At	840 alternations a second	the current	begins to be	disagreeable.
,,	960 ,,	,,	,,	painful.
,,	1440 ,,	,,	,,	pain ceases.
,,	a point not determined ,,		,,	sensation disappears.

Motor effects.—These also vary with frequency. As frequency rises from zero, the muscles steadily contract up to a certain point ; then they gradually relax.

PART II

CHAPTER I

The Electrotherapeutic Outfit

The requirements are:

1. *A "combined" battery, i. e.* a switchboard giving control both of continuous current (galvanic) and of induction coil current (faradic) (Fig. 56).* The source of supply for con-

Fig. 56.—A "combined" battery.

* Schall.

tinuous current may be either thirty to sixty Leclanché cells, or continuous dynamo current from modern electric lighting installation. The induction coil ought to be of the "sledge" type.

2. The battery must have a double current selector, *i. e.* a means of throwing cells into action one by one commencing with any particular cell; also a rheostat by means of which resistance may be gradually diminished to the passage of a current. For public supply currents a rheostat on the shunt principle is necessary (see current from the main, p. 73).

3. Whether the source of supply be a battery or continuous current dynamo, there must be a "current changer" for changing quickly from continuous to alternating ("galvanic" to "faradic"), and a "pole changer" or reverser for changing the sign plus or minus of the electrode, *i. e.* changing quickly from positive to negative or *vice versâ.* A "current combiner" for using both currents together is also desirable (see Fig. 56).

4. A milliampèremeter (see p. 21).

5. A set of electrodes.

6. Electrolysis needles of various kinds.

In addition to the above the medical man who devotes himself especially to electro-therapeutics will have—

7. A voltmeter for measuring the E. M. F. of the battery or any particular cell, or measuring the resistance of various parts of the circuit. Many milliampèremeters are also voltmeters (see p. 22).

8. A static machine and appliances (see p. 57).

9. Apparatus for obtaining currents of great frequency and high potential (see p. 64).

10. A hydro-electric bath.

11. Cautery battery (Fig. 57), or arrangements for heating cauteries from light mains (see below), with set of cautery instruments (Fig. 58) and universal handle (Fig. 59).

In further explanation of the foregoing points it may be stated that: For a stationary battery there ought to be forty

to seventy cells of the Leclanché type, *i.e.* with zinc for the positive, and carbon for the negative plate. They may be

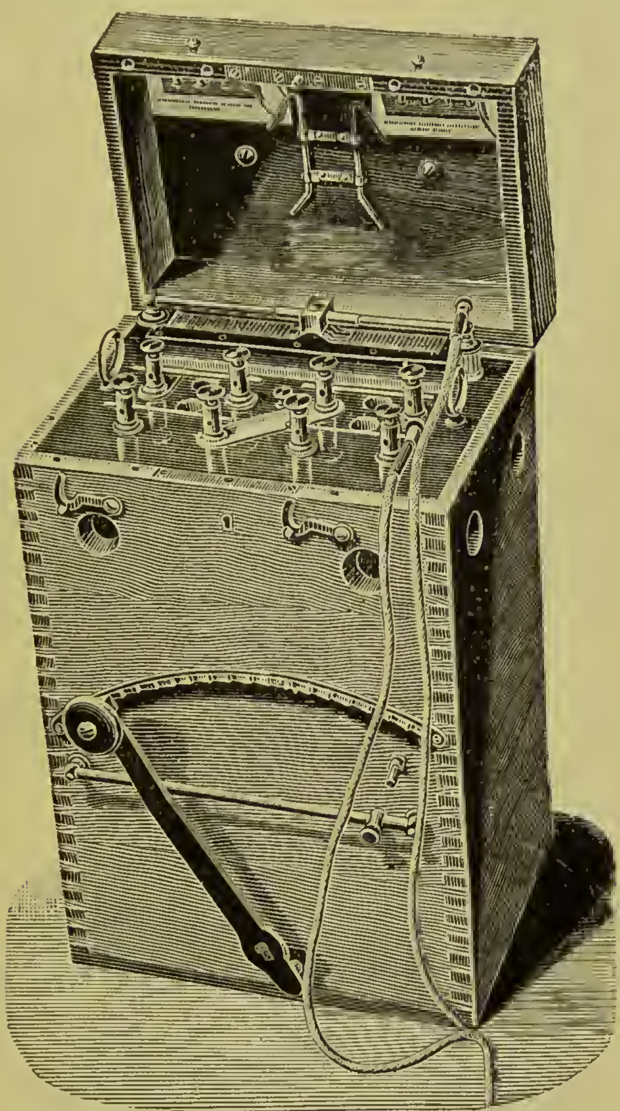


Fig. 57.—A cautery and light battery.*

fluid cells or dry cells. They should be arranged "in series" in a cupboard or cabinet. A wire attached to the carbon, and taken to a terminal or "binding post" will be the positive pole. The terminal connected to the zinc plate will be the negative pole (see p. 10). A rheostat and cell collector and a milliampèremeter are placed in circuit, and the wires carried to a switchboard, with terminals or binding posts plainly marked positive or negative. The same switchboard should also give

* Schall.

control of the induction coil by suitable switches. It is necessary for purposes of diagnosis to be able to change

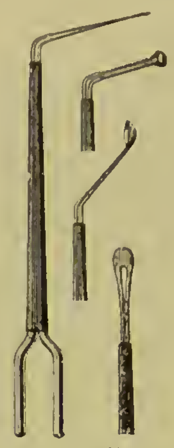


FIG. 58.—Cautery burners.

quickly from one current to another; and in treatment, to be able to pass both currents through the part at once. This is

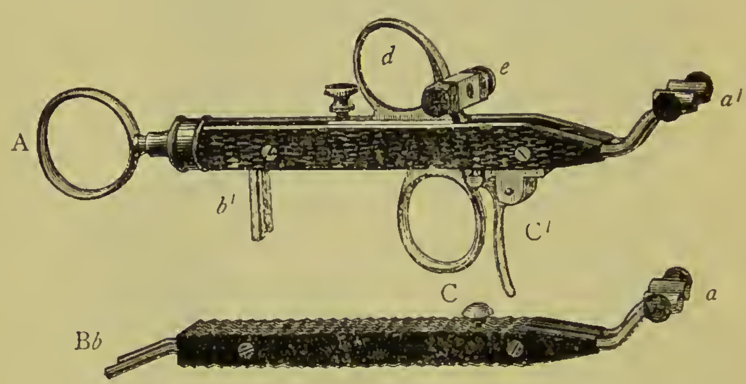


FIG. 59.—Universal handle for cautery.

effected by means of a "current changer" and a "current combiner." There should also be a "pole changer," for quickly altering the sign of the electrode from positive to negative (plus to minus) or *vice versâ.*

These are shown in the portable combined battery (Fig. 56). It is "portable," inasmuch as it contains only forty small cells; and "combined," as it contains both a continuous current battery and an induction coil. If the continuous current is desired, the switch is turned to G; for the Faradic it is turned to F; and if then the switch on the extreme right be

turned to N (normal), the terminal marked plus is positive, and the other is negative. If the same switch be turned to R (reverse) the true sign of the terminals is also reversed. If it be desired to use both currents at the same time, the switch stands midway between G and F; then the patient will receive both currents simultaneously. The double cell-selector shown is known as a "crank collector," *i.e.* by turning the crank any number of cells from one to forty may be gradually introduced into the circuit; or any particular cell or combination of consecutive cells may be selected.

The Rheostat or current controller is a device for gradually turning "off" or "on" the current, by introducing or removing resistance from the circuit smoothly and without breaks. Its purpose is the same as that of the current selector, but its action is more smooth. A graphite rheostat with a mercury contact is shown in Fig. 60. Many forms of rheostat are

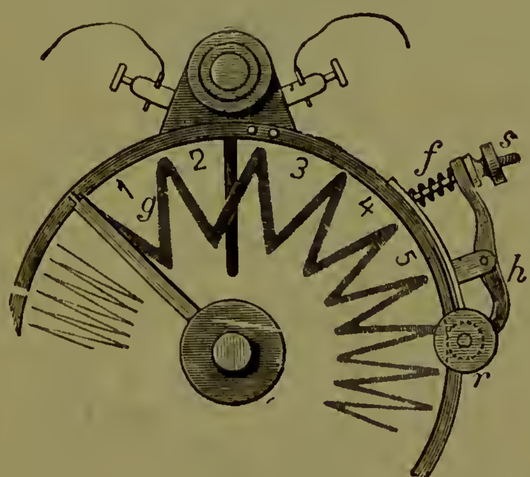


FIG. 60.—Rheostat with mercury contact.

made. Excepting when very small E.M.F. is used, all rheostats ought to be so arranged that the patient is not "in series" with the electric source (whether the latter be cells or dynamo), but in a "shunt" circuit. This allows only the E. M. F. necessary for the particular purpose in hand to be used, see p. 73, "Current from the Main." It has been objected that graphite is unsuitable for rheostats, inasmuch as

its R is apt to vary. This is of little moment, as the milliampèremeter is always in circuit to denote the current passing. Water rheostats are often used, but they are rather clumsy, and not capable of any very quick movement, and they always leave a certain amount of resistance in circuit. These are not very valid objections, and the rheostat of Professor Bergoniè, Fig. 61, is a most practical and useful instrument.*

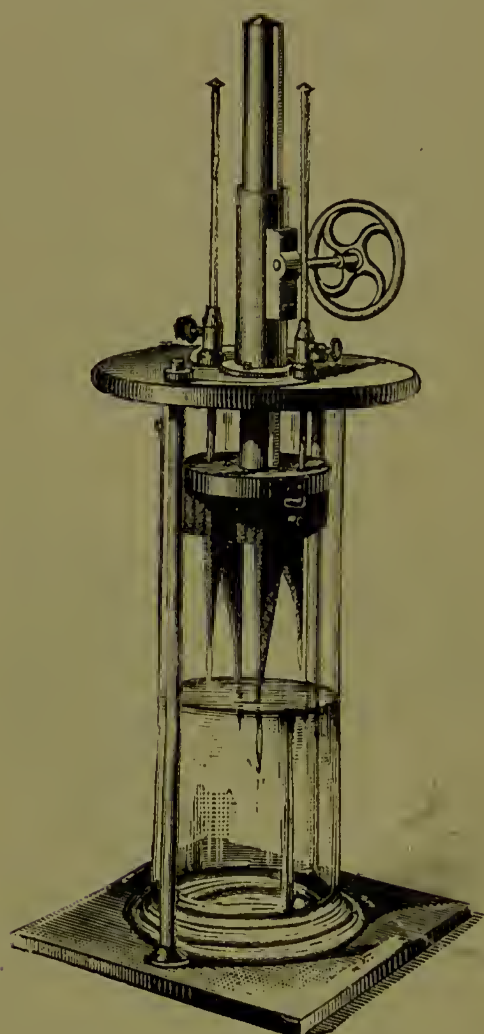


FIG. 61.—Bergoniè's rheostat.

Milliampèremeter (see p. 21).—"It is no more right to

* The writer can recommend from personal experience the Willms current controller (Isenthal) which is capable of smoothly throwing in R. from ·06 to 200,000 ohms.

administer electricity without measuring it than to administer drugs by guess work." The galvanometer most often used in this country is, perhaps, that of Edelmann, which depends upon the principle of the deflection of a magnetic needle by a current, see Fig. 56.

The Induction Coil, Figs. 30 and 56, should be of the "sledge" type, *i. e.* one in which the secondary can be pulled over the primary. It is necessary to be assured that the contact-break works evenly, and that its rapidity of vibration can be easily regulated. A medical induction coil should have a means of using the current from the primary or secondary wire at will. The rapidity of the interrupter or contact-break is usually regulated by altering the spring by a screw. A more perfect means than either is to have the interruptions made by a motor driven by a separate current, distinct from that which works the coil (see p. 45).

The Electrodes.—It is usual to call the pad which applies the current to the body the electrode, and the wire that connects the electrode with the battery the conducting cord or "rheophore." Several sizes and shapes of electrodes must be available. A "set" might consist of—

(1) A "testing electrode," say ·5 to 1·5 cm. ($\frac{1}{4}$ to $\frac{5}{8}$ inch) in diameter, having an interrupter in the handle.

(2) A small electrode between 2 and 3 cm. in diameter ($\frac{3}{4}$ to $1\frac{1}{4}$ inches) used in testing large muscles, applications to facial muscles, eye, etc.

Medium electrode about 7·5 cm. in diameter (2 or 3 inches) for applications to neck and limbs.

Large electrodes for muscular masses, deep seated parts of spine, sciatic nerve, &c., varying from—

10 cm. × 15 cm. to 10 cm. × 25 cm.

4 in. × 6 in. to 4 in. × 10 in.

A roller electrode.

An Apostoli pad, or the "Massey" wired pad of absorbent cotton, or other large soft electrode to cover the entire abdomen.

Cautery.—There are three ways of electrically heating the cautery wire. (*a*) A primary battery; (*b*) accumulators; (*c*) electric lighting mains.

The battery must be able to give a current of from 10 to 20 ampères; and in order to keep the current constant, even for a few minutes, large sized cells are necessary. On the other hand the R. of platinum burners and other parts of the apparatus is small; therefore two cells in series, of 1·5 volts each, are sufficient. Suppose with this E. M. F. the R. of platinum burners and conducting wires to be 0·06 and the R. of large cell also 0·06: Then:—$\frac{3}{0{\cdot}06 + 0{\cdot}12} = 16{\cdot}6$ ampères. It is evident that the conditions required in such a battery are very different from those required for passing a current through the body. In the latter case the R. is very high, therefore a high E. M. F. (a large number of cells) is required. But the cells can be small because the currents required are only small fractions of an ampère; whilst in a cautery battery the current required is more than 1000 times as strong, therefore the cells have to be of large size to supply such a current even for a few minutes; but the R. is so low that a couple of cells supplies a sufficient E. M. F. to overcome it.

Here attention may again be drawn to the different ways of "connecting up" cells. They may be connected in series, in parallel, or in groups (see Chapter III). "Series" connection is adapted to overcome high R., *e.g.* that of the human body. If connected in "parallel" the E.M.F. does not increase but the surface of the plates of the battery increases, two similar plates being connected together; and therefore the internal R. of each cell diminishes. Another important point is that we double the constancy by doubling the size of the plate, for large cells do not polarise so quickly as small ones do. Fig. 57 is a battery adapted either for lighting a small lamp or heating a cautery. The lamp requires, say, six volts for incandescence, therefore the four cells are joined in series. For cautery purposes 3 to 4 volts is sufficient, therefore the 4 cells

are connected in groups of two, whereby the E. M. F. is halved and the size of the cell doubled. The best cells for this purpose are bichromate cells (see p. 13), as their E. M. F. is nearly 2 volts. Leclanché dry cells will answer the purpose. They are very convenient and sufficient for occasional use for a few minutes at a time. But accumulators are much preferable where there are facilities for re-charging, *i. e.* where a continuous electric light circuit is available (see p. 76). They ought to be able to discharge 15 ampères without injury. A rheostat, *i. e.* a resistance to regulate the strength of currents is necessary for all cautery batteries, and also indispensable when using accumulators.

CHAPTER II

The Human Body a Source and a Conductor of Electricity

Animal electricity.

It is quite certain that animal tissues and fluids can produce and conduct an electric current. Galvani proved this. Laying the nerve-muscle preparation on a glass plate, the nerve was raised with a glass rod, and then being allowed to touch the muscle, a contraction occurred. This was the demonstration of animal electricity, the existence of which Volta had denied. On the other hand Volta proved his assertion (which Galvani had denied) that metals in contact with a fluid produce an electric current. The demonstration of this latter fact was nothing less than the discovery of the voltaic cell, which has done so much for civilisation since.

It was Du Bois Reymond who first clearly distinguished between animal and metal currents; he considered, and the contrary is not yet proved, that a natural electric current exists in normal resting muscle—" current of rest." During the action of the muscle he demonstrated the existence of a current in a direction opposite to the rest current. This was called the " negative variation," now known as the " current of action." Hermann combats the opinion that a muscle at rest and free from injury, produces any current; and holds that the so-called current of rest is the result of chemical or other inequalities due to the injury. At present the opinions on this subject held by English physiologists are as follows :*

(1) Normal muscle or nerve gives no current.

* To avoid the polarisation which must occur when ordinary electrodes are applied to living tissue, it is necessary in physiological experiments to use " non-polarisable " electrodes, *e.g.* zinc rods dipped into tubes containing zinc sulphate, the lower end being filled with clay moistened with 0·6 per cent. normal saline solution or water.

(2) Local injury produces a current from the injured to the living part.

(3) Local action produces a current from the active to the resting part.

Thus an injured or an active muscle produces electromotive force; and as in the Daniell cell the current goes from the active plate (the zinc) to the copper, so does current travel in the injured muscles from the injured part to the sound part. When the circuit is completed through a galvanometer, of course the direction is reversed; and it is usual to describe the direction of a current in its relation to the galvanometer.

The "negative variation."—If a muscle giving the muscle current ("injury current") be tetanised, an "action current" will proceed from the uninjured to the injured part, *i. e.* from the part more capable of function to the part less capable of function. This current, being in a direction opposite to the muscle current (injury current), tends to cut down or diminish the latter, and this diminution is the "negative variation" of du Bois-Reymond, the "action current" of Hermann.

The "diphasic variation."—A contraction-wave propagated along the fibre of an uninjured muscle is accompanied by an electrical disturbance travelling from the active to the resting part; and this variation (as revealed by a galvanometer uniting two electrodes placed at an interval on the surface of the muscle) is double or diphasic, for the obvious reason that the action is not simultaneous throughout the muscle, but requires time for its transmission.

The electro-motive action accompanying voluntary muscular contraction in the human subject has been demonstrated by du Bois-Reymond, and that accompanying tetanic contraction from electrical stimulation by Hermann.*

* It has been attempted to explain some of the foregoing phenomena on the following physical principles. "It can be shown that mechanically produced derangements in shape produce the electric state, and conversely that variations in the electric state are accompanied by derangement in shape. According to d'Arsonval similar phenomena occur in all liquid and semi-liquid bodies, which present a surface that can be disturbed mechanically. Therefore it is sought to explain action currents by variation in surface tension (and consequently in the

There is a variation of electrical potential from the beat of the human heart. It is by some regarded as proved that the white columns of the spinal cord give electrical signs of nerve action, and even that action currents are manifested by the grey matter of nerve centres. The skin of all animals is traversed by an electrical current from without inwards. The action of light upon the retina causes an electrical change; in other words a current accompanies retinal activity as it does muscle activity. Indeed it is probable that electrical phenomena always accompany vital action.

The animal body a "conductor."

Having seen in what way the living body is a *source* of electricity, the more practical point now remains to be dealt with, viz. that the body is a *conductor* of electricity. It is quite certain that an electric current can be made to traverse every tissue and organ of the body, even the bones and most deeply seated nerve centres. Follow the flow of a continuous current as it travels through the body from point to point. Lying in its path are the various structures and fluids of the organism, skin, muscle, gland, tendon, aponeurosis, nerve tissue, blood. All of these have, from the electrical standpoint, a very high "resistance," *i. e.* they are bad conductors of electricity. But by far the worst conductor amongst them is the epidermis. It is almost entirely owing to the high resistance of the latter when dry, that the total resistance of the body when measured say from hand to hand or foot to foot, is seldom less than 1000 ohms; and it may be much more. Yet under other conditions as, *e. g.*, in the electric bath, when the skin is soaked and a large surface is available for the entrance and exit of the current, the present writer has calculated body resistance to be as low as 300 ohms. It is thus evident that the resistance of the body cannot be spoken of as a fixed quantity. It varies in fact with the moisture of the skin, the size and moisture of the electrodes, the direction of the current (*i. e.* whether it is longitudinal, or transverse to the structure through which it

electric state), which is due to the internal mechanical distortion that occurs in every living tissue which is undergoing a spontaneous change of shape."

passes), and the cutaneous hyperæmia that results from the passage of the current. From these considerations arises the necessity for having the coverings of the electrodes *wet* in order to insure a good "conducting joint" between the metal and the dry insulating epidermis. It is also owing to the production of certain of these conditions, that during an electrical application there is often to be noticed a more or less rapid increase in the current, although the number of cells has remained the same. The cutaneous hyperæmia induced by the application, and the moisture of the skin, have in fact diminished the resistance, and so increased the current.

Notwithstanding the number of factors that enter into the question, it may be stated that the total resistance of the body is, for practical purposes, almost entirely made up of the resistance of the skin. It may also be added that this question of body resistance is not a very important one excepting in the case of the electric bath, inasmuch as under other conditions the galvanometer measures the current in absolute units. It does so also in the case of the electric bath, but *then* it registers a current that is passing through a composite conductor consisting of the body and the bath water; and the only way of measuring the body's share of current is to know the resistance of the body relatively to the resistance of the water (see "Hydroelectric Bath").

Once through the skin the current will be divided between the various structures in an inverse ratio to their resistance. Thus it will meet with the greatest resistance in the bones and the least in the muscles,—in the following order: muscle 1, tendon 1·8 to 2·5, nerve 1·6 to 2·4, cartilage 1·8 to 2·3, bone 16 to 22. It is evident that the greater the amount of fluid in the tissue the better it conducts electricity.

Method of measuring resistance of the body.

For finding the R. of ordinary electrolytes the method of Kohlrausch (with a Wheatstone's bridge * and a telephone) is useful. But in the case of such an electrolyte as the human

* For the method of measuring R. by the Wheatstone "bridge" or balance, see S. Thompson's 'Electricity and Magnetism,' or other electrical text-book.

body even approximate silence cannot be attained on account probably of condenser effects. Body resistance may be measured in several ways:

Eulenberg's method.—Electrodes of a certain size (25 × 29 cm.) are applied to the region of the body whose R. is to be ascertained. A Faradic current (to prevent polarisation) is passed, and the deflection measured in milliampères upon the electrodynamometer (Giltay-Bellati). Then a known R. is gradually substituted for the body until the deflection is the same.

Prof. Bergonié's method.—The principle is to arrange in parallel the R. to be measured and his rheostat (see p. 88) previously calibrated, and these are led to a differential telephone. By diminishing or increasing the R. in the rheostat a moment comes when sound ceases: Then the R. in the rheostat is read off, which obviously equals that of the part of the body to be measured.

The R. of the body has been found to vary in certain conditions of disease (see "Electro-diagnosis").

Current diffusion.

The body conducts electrical currents chiefly by its saline constituents. Now the behaviour of a current in a saline solution has been examined by direct experiment. It will be seen by Fig. 62 that in a narrow conductor the lines of

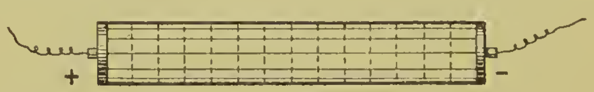


FIG. 62.

current flow seem to cross the dotted lines (the lines of "equal potential") at right angles. This has been illustrated by imagining a current of water flowing down a narrow staircase, when the lines of equal potential would be represented by the edges of the steps. But if the conductor be a good deal wider than the electrodes are, like that represented in Fig. 63, the dotted lines, that is the lines of equal potential, show a curve; therefore the lines of current flow must curve also, as the potential lines must necessarily be crossed at right angles. In other words the current, on entering such a

conductor as the body, diffuses itself; that is to say divides into many "derived" currents, and the intensity is the sum of the intensities of the derived currents. This is known as

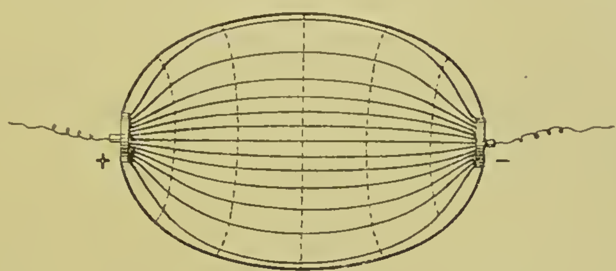


FIG. 63.

Kirchoff's law. It is true that the body is not a strictly homogeneous conductor like a saline solution; still the general configuration of current diffusion would be as represented, only the lines would be more or less irregular, the current being deflected in proportion to the resistance of the tissues it encounters, and chiefly, therefore, by the bones.

This question of current diffusion leads to a consideration of its opposite, viz. current concentration. The physiological effects of the unbroken flow of a continuous current are proportional to the concentration of that current (its "*density*") as well as to the *intensity* (milliampères) and *duration* of the application; *e. g.* the effect of a current of 6 milliampères on 6 square centimetres of surface will be half as great as the effect of 6 m.a. on 3 square cm. of surface. Fig. 63 shows that in a wide conductor the largest number of lines, *i.e.* the greatest current density, is in the direct line between the electrodes. Here the electrodes are of the same size, and, therefore, the current is of equal density at each. The distribution of current in such a conductor as the body is similar to that in a saline solution, with the exception that there would be, as just stated, wavings and irregularity, due to the different resistance of the various tissues. Current density.

Effects upon the animal body of electric currents.

Now arises the question: How is the current travelling, and what work is it doing *en route?* In other words what are the effects of the current upon the body, and how does electricity become a remedy? These points may be studied under two headings:

(1) Effects common to the body and to inanimate conductors. (2) Effects which depend upon the body being a living animal organism.

Under the first of these classes come electrolysis and cataphoresis.* Under the second, excitation, electrotonus, bactericidal action.

I. Effects common to the body and to inanimate conductors.

(*a*) *Electrolysis.*—Whenever an electric current passes through certain chemical substances in solution there is a splitting up of the substance into its elements; and this occurs whether the current be weak or strong. It is thus that a salt is split up, the acids being collected at the positive pole and the alkalies at the negative pole. The freed elements at the positive pole are called "anions," those at the negative "kations." Now although such changes are most marked at the poles, it is certain that some kind of splitting up and re-arrangement of molecules occurs throughout the circuit, *i. e.* in the interpolar region; in other words an electro-motive force applied to most chemical compounds when liquefied causes a continuous procession of the matter and associated electricity, the positive in one direction and the negative in another (Figs. 64, 65, 66). Absolutely pure water is a non-conductor, but its saline impurities make it a conductor, and it is electrolysed into its components; oxygen (the anion) appearing at the positive pole, hydrogen (the kation) appearing at the negative pole (Fig. 65). This is electrolysis or electrolytic conduction, and any liquid, semisolid, or moist porous body, the molecules of which have been partly decomposed into ions, is called an electrolyte. Electrolysis is "a process of convection rather than of conduction," *i. e.* the electricity moves with the moving

* The heating effect of an electric current on living tissue is too insignificant to require consideration from the electro-therapeutic standpoint.

matter, and it proceeds according to definite and fixed laws. Now the animal body is an electrolytic conductor, and remembering the important point that electrolytic conduction is invariably accompanied by decomposition of the chemical compound, *i. e.* by the disassociation of its atoms, it is evident that to apply an electro-motive force to a living body is to give play to an agent which must of necessity modify the component part of the tissue through which it passes, by the

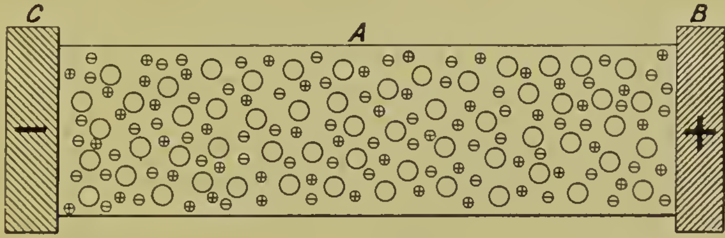


FIG. 64.—Arrangement of molecules before electrolysis.

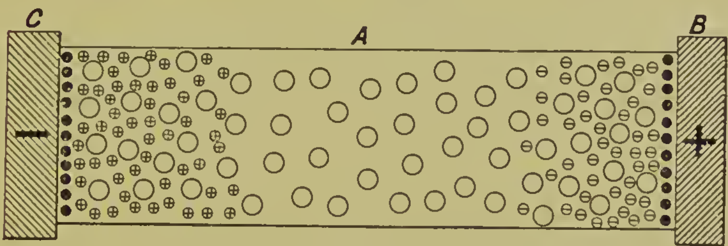


FIG. 65.—Showing electrolysis.

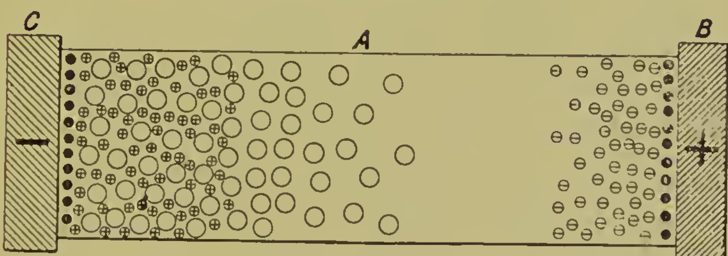


FIG. 66.—Showing electrolysis and cataphoresis.

necessary "decompositions, recompositions, and liberation effects, the constant changes between molecule and molecule" that accompany the passage of a current through an electrolyte. It is thus that electrical energy, brought to bear upon the body, may influence those processes of integration, assimilation and excretion that collectively constitute metabolism.

Those medical and other philosophers, whose present craze

it is to explain everything on the doctrine of suggestion, may be invited to remember that the living body is an electrolytic conductor, and to consider for a moment what electrolytic conduction means.

The destructive action of a current upon living tissue depends upon the formation, from the tissue itself, of oxygen and acids (hydrochloric, sulphuric, and phosphoric) at the positive pole, and hydrogen and alkalis (caustic soda and potash) at the negative pole. These newly-formed products act, in their turn, on the neighbouring sound tissues, and eschars of distinctive characters, appear at the two poles. At the positive pole the eschar is dry, partly because the fluids have been drained away by cataphoresis; at the negative pole the eschar is moist, partly due to the fact that the fluids have been transferred thither by cataphoresis. The negative eschar is perhaps the smoother and less contractile, although the slower to heal. The caustic effects characteristic of each pole have been utilised in therapeutics, especially by Tripier and Apostoli under the name of "galvano-chemic cauterisation."

(*b*) *Cataphoresis*.—When a galvanic current passes through an electrolyte, not only is there a migration of the ions and an accumulation of certain constituents of the electrolyte at either pole, in other words, not only is there *electrolysis*, but at the moment that the ions begin to migrate there takes place also a transference of the non-dissociated molecules of the electrolyte in a definite direction, usually the direction in which the current flows. This is called cataphoresis. The process which is going on may be realised by diagrams 64, 65, 66 (after Meissner). Let A represent a moist conductor; the + circles are ions charged with positive electricity, the − circles are ions charged with negative electricity; the large circles stand for the undecomposed molecules. A current is passed through this electrolyte and migration of the ions takes place; anions and kations are formed, collecting respectively at the positive and negative

poles. But a further change is taking place; certain of the ions have given up their electricity, and are being eliminated from the body in a gaseous or metallic form. These are represented by the row of black circles at each pole. In the third diagram are shown molecules not decomposed into ions, which have migrated under the influence of the current from the positive to the negative pole. There is an actual mechanical transference of material from the anode in the direction of the cathode. This is cataphoresis.*

II. Effects depending on the body being a living organism.

(*a*) *Excitant action.*—Electrical stimulation, by influencing motor nerves, throws muscles into activity, with corresponding alteration in circulation and nutrition. This excitant action for the most part depends upon current variation.† It is shown in nerves of sensation by the sense of pricking and heat, which with a strong current developes into painful burning. The negative is the more painful pole. Doubtless electrolytic action plays an important part in the production of these sensory phenomena, but the current has certainly an excitant action of its own upon sensory nerves as well as upon motor nerves. Bringing this excitant action to bear upon nerves of common sensation, ingoing impressions are originated by which the great cranio-spinal centres may have their nutrition and function altered. Vasomotor nerves also respond to electrical stimulation by various circulatory and nutritive changes; a redness appears at each pole; this shows immediately at the anode, but sometimes at the cathode there is first a pallor of the skin, followed by slight reddening which does not develope into intense redness until the current has ceased to flow. There is also a local elevation of temperature, greater under the anode than under the cathode (Bordier). The stimulating effect of the current, besides acting through the agency of nerves, acts also on muscular fibre, both voluntary and involuntary, by direct stimulation

* For other theories on cataphoresis see chapter on "Cataphoresis."

† Although with weak currents these effects are due to opening and closing of the circuit, a strong current stimulates throughout the duration of its application, producing continuous contraction.

of the cell. It is also probable that glands and secreting organs and the tissues of the body are influenced by a continuous current independently of their innervation.

The action of a varied current on the neuro-muscular apparatus is embodied in what is known as Pflüger's law of contraction, and will be further studied at p. 108. It is not the absolute strength and density of a steadily flowing current to which the neuro-muscular system reacts; it is to the changes of potential, and the rapidity with which such changes follow each other, *i. e.* the suddenness with which the change is made, that the excitant effect is due.

It is an accepted physiological fact that the nerve is excited at the kathode when the current is made, at the anode when the current is broken. In the human subject the action of the two poles on muscular contractility is as follows:

Normal law of contraction.

1. With a weak current (1 to 3 m.a.) there is a contraction only due to the closing of the circuit with the negative pole applied to the part—"kathodic closure contraction" (K.C.C.).

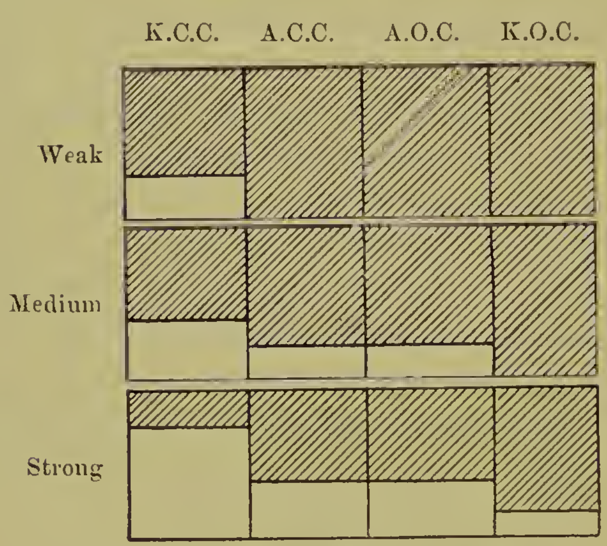


FIG. 67.—The "normal polar formula."

2. With a medium current (5 to 8 m.a.) there is a stronger contraction, with closure of the negative pole. Two contractions also occur with the positive pole applied, one at closing, and one at opening—"Anodic closure contraction," and "anodic opening contraction" (A.C.C., A.O.C.).

3. With a very strong current (above 15 m.a.) there is tetanic contraction at kathodic closure, a contraction at anodic closure and anodic opening, and a slight contraction at kathodic opening. These are shown in Fig. 67, where the non-shaded parts represent the force of the contraction.

It thus appears that there is both an opening and a closing contraction, whether the kathode or the anode be over the nerve. At first sight this might appear to contradict the above stated law that the nerve is excited at the kathode when the current is made, at the anode when the current is broken. The study of Fig. 68 will explain this. It is evident that

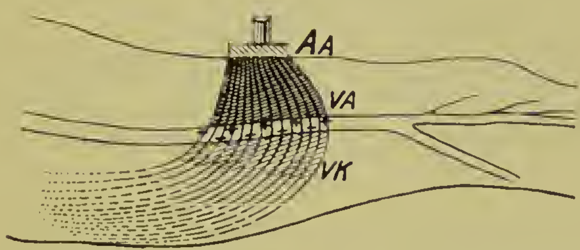


FIG. 68.—Showing current "density" and "virtual" anode and kathode.
AA. Actual anode. VA. Virtual anode. VK. Virtual kathode.

owing to the laws of derived currents, the current density is at its greatest immediately beneath the electrode. This is the "polar zone" shaded darkly, and this region is of the same sign as the electrode, *i. e.* positive if the electrode be positive, negative if the electrode be negative. Having entered at the polar zone (dark shading) the current spreads out (*i. e.* becomes less dense), and leaves the nerve at the "peripolar zone" (light shading). Now an anode is defined as the point of entry of the current into an electrolyte, a kathode as the point of exit; therefore, in this case the polar zone being anodic, the peripolar zone is kathodic. In fact, by placing an actual electrode on the skin *over* the nerve there have been created two virtual electrodes *on* the nerve. These may be defined "the portion of the tissues surrounding the nerve from which, and into which, the current passes in its course through the nerve."* These regions, as already said, are

* de Watteville.

represented by the light and dark shading in the figure; thus, whether an anode or kathode be placed *over* the nerve, there are two *virtual* electrodes *on* the nerve; one at the dense polar zone immediately under the electrode, the other at the peripolar, less dense zone, away from the electrode.

Remembering that the kathode is the stronger stimulus, and that the density of the current is also an important factor in producing stimulation, the order of appearance of the contractions, and the reason for this order may be tabulated thus (after Waller):

In the	The nature of the stimulus is	The situation of stimulus is	Numerical value.	
K. C. C.	Kathodic	Polar	$=1$	Best stimulus in best region.
A. C. C.	Kathodic	Peripolar	$=\frac{1}{2}$	Best stimulus in worst region.
A. O. C.	Anodic	Polar	$=\frac{1}{2}$	Worst stimulus in best region.
K. O. C.	Anodic	Peripolar	$=\frac{1}{4}$	Worst stimulus in worst region.

It is evident that the current density in the two regions must be influenced by the nature of the tissues in which the nerve lies embedded; and as this differs in various situations it sometimes happens that A.O.C. precedes A.C.C., *i. e.* the greater density in the polar zone neutralises the greater energy of the virtual cathode at the peripolar zone. There is another complication connected with opening contractions, viz. that not only is there a simple fall of potential to zero at the opening, but there is the closing of a polarisation current; so that the excitation of opening consists not only of the battery current but also of the negative closure of polarisation.

The numerical value given to the different excitations is explained by considering the two great factors that enter into the production of an excitation, viz. the exciting power of the active pole and the density of the current at the point excited. Let C represent the extent of the contraction, E the exciting power of the pole, and D the current density, we have the equation $C = E \times D$. If the power of kathodic excitation be taken as 1 and anodic excitation as $\frac{1}{2}$, and the density of the current under the electrode, *i. e.* in the polar zone (shaded

dark) be 1, and the density in the peripolar zone (light shading) be $\frac{1}{2}$; then in the case of a kathodic closure the force of the contraction will be $1 \times 1 = 1$. But at opening of the current the excitation will not be at the real kathode but at the virtual anode (light shading), therefore the force of the contraction will be $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$. Suppose the electrode to be anode the closing excitation will not be at the actual anode but at the virtual kathode (light shading), and the force of the contraction will be $1 \times \frac{1}{2} = \frac{1}{2}$. At the opening of the current the excitation is at the actual anode (dark shading), and the force of the contraction is $1 \times \frac{1}{2} = \frac{1}{2}$.

(2) *Electrotonus.*—A continuous current passed along a nerve increases the excitability of that nerve at the cathode (catelectrotonus), and diminishes its excitability at the anode (anelectrotonus); but on opening the circuit there remains at both poles a condition of excitation for a longer or a shorter time. In attempting to arrive at such results in practice, it is evident that although these electrotonic modifications of excitability exist beyond doubt, and can be shown in the excised nerve, it is a very different thing to be able to induce, to localise, and to limit them in the undisturbed living nerve. It has been already shown in Fig. 68 that it is impossible to submit any large extent of nerve in the living subject to the influence of only one pole. The diffusion of current in the tissues, and the condition of the tissues make it evident that in a given nerve the current has a series of points of entry, and of exit; that there are, in fact, two zones of opposite polarity, and that therefore the physiological facts of electrotonus cannot afford a basis for any wide general application to therapeutics.

(3) *Bactericidal action.*—In ordinary therapeutic applications this need not be considered. The experiments of Apostoli and Laguerriere show that to secure the destruction of microbes a current of fifty milliampères of positive pole must be used for five minutes. The effect is doubtless chemical, the cathode is without effect.

Choice of pole in electro-therapeutics.

From the foregoing study of the properties of a continuous current as it travels through the body we may deduce rules for the choice of pole in therapeutic applications. Positive pole,—sedative, drying, depleting, hæmostatic, capable of diffusing certain medicinal substances into the body, microbicidal over fifty milliampères. Negative pole stimulant quickens absorption, causes congestion, increases moisture, dilates canals, diffuses certain medicinal substances, and is the more destructive electrolytically.*

A strong continuous current (100 milliampères) of considerable density is probably injurious to living tissue, and depresses its nutrition, whilst a mild current (five to eight milliampères) stimulates and improves nutrition. Thus, in dealing with a neuritis, a muscular atrophy, or diseases of the cord, a strong current passed through the affected structure will assuredly make bad worse. On the other hand, there are cases of localised thickenings and induration of tissue, chronic fluid exudations, fibrous adhesions, peri-articular mischief, and post-rheumatic conditions of a chronic kind, where, if pain be absent, a strictly localised action with strong dense currents and the preponderance of the cathode is indicated.

For the physiological action of induction coil currents see p. 45, of static electricity p. 63, of sinusoidal currents p. 79, of currents of great frequency and high potential p. 68.

Death from electric currents.

The exact physiological mechanism by which death or danger is brought about when strong currents find a path through the living body is not yet authoritatively settled. According to the most recent experiments (those of Prévost and F. Battelli †) it would appear that high tension alternating currents (4800 or 2400 volts in the case of the dog, 1200, 600, or 240 in the guinea-pig), applied from a fraction of a second to one or two seconds from head to feet, produce strong convulsions or tetanus with opisthotonos, loss of consciousness, transitory or permanent prostration, arrest of respiration, loss more or less prolonged of the corneal reflex and knee-

* Massey.

† 'Académie des Sciences,' March, 1899.

jerk. Blood-pressure is first raised whilst the heart-beat is accelerated, and falls when the latter diminishes. The auricles are arrested in diastole whilst the ventricular contractions continue. The animal may come to itself again with or without artificial respiration. In the case of currents of relatively low voltage (120 to 10 volts) tetanus is produced with the electrode in the above-named position. Fibrillary tremors of the ventricles supervene if contact has continued for at least one second. The auricles continue to beat as when electrical currents were applied directly to the naked heart. Further, the heart, in a state of tremor by the application of these low tension currents, may be seen to resume its contraction under the influence of a high tension current if the latter be applied within fifteen seconds. Respiration is arrested, but artificial respiration may save the animal. The rabbit does not die when the fibrillary contractions of the ventricles appear. The action of the heart becomes re-established without restorative measures. No post-mortem appearances characteristic of death by electricity could be established; but the most constant was intra-cerebral hæmorrhage after long applications.

CHAPTER III

Electro-diagnosis

Technique of electrical exploration (continuous current).

If a continuous current be applied to an uninjured nerve or muscle in the living body, the extent to which that nerve or muscle is excited will vary (*a*) according to the pole which is applied; (*b*) according to whether the circuit is opened or closed; (*c*) according to the intensity used. And inasmuch as this current acts as a stimulus at the moment that the circuit is closed (closure contraction), and also at the moment the circuit is opened (opening contraction*), and as this occurs at both poles, it is evident that the neuro-muscular apparatus may be excited in four different ways. In other words there are to be systematically studied four "electrical reactions," viz. one at closure and one at opening with the negative pole applied to the part under observation, and one at closure and one at opening with the positive pole applied.

Normal reactions.

Now selecting a normal "subject"† let the large or indifferent electrode (having a superficial area of say 100 sq. cm.) be well wetted in hot water, attached to the positive pole (anode), and placed upon the sternum or abdomen, or most conveniently just below the back of neck. The electrode may be kept in position by means of a towel crumpled up and pushed in between the electrode and the clothing. Taking now the "small," "active," or "testing" electrode (having a diameter of say 1·5 cm.), let it be well wetted and attached to the negative pole (kathode). Then holding this electrode by its

* There are effects known as "Duration" contraction during the steady flow of a strong current, and perhaps during the steady flow even of ordinary currents there is a shortening of the muscle.

† The experimenter will do well to begin by trying upon himself.

interrupting handle (the finger upon the interrupter) place the electrode upon a motor point. Suppose the latter to be that of the ulnar nerve at the elbow, about an inch above the condyle, at the inner border of the triceps. Now with one hand holding the electrode upon this point, with the other hand move the rheostat handle or the current collector, until an electro-motive force of 6 or 8 volts (5 or 6 cells) is secured. Continue to take out R. or to put more cells into action, and as the electro-motive force is gradually increased, *i.e.* as fresh cells are added, or R. taken out, keep closing the circuit at short intervals by means of the finger upon the interrupter in the handle of the electrode. At one of these closures a muscular contraction will appear—a "short, sharp, well-defined jerk." Now keeping the circuit closed, note the intensity of the current as registered by the galvanometer. It may be one milliampère.* In this case the testing electrode being attached to the kathode, and the contraction having been noted at the closure of the circuit, it is therefore a "kathodic closure contraction" (K.C.C.); and the current necessary to produce it being 1 m.a. (in this particular instance) the fact is expressed K.C.C. = 1 ma. Now the circuit being kept broken by means of the interrupter, but with the testing electrode still upon the same motor point, move the switch upon the element board, which has hitherto been pointing to normal (N.), across to the reverse side (R.). The testing electrode which was before kathode now becomes anode. Put back the handle of the cell collector or the rheosat to zero and gradually throw into circuit one cell after another or take out resistance by means of the rheostat as before. Still keep making occasional closures by means of the interrupter. A moment will come when another contraction occurs—"anodic closure contraction" (A.C.C.). Keeping the circuit closed, again read the galvanometer. It perhaps now may register 2 ma., therefore A.C.C. = 2 ma. But only one milliampère was required to produce

* The intensity required to produce contraction will vary with the stoutness and muscular development of the individual and other circumstances affecting current density.

the "kathodic closure contraction;" therefore kathodic closure contraction is a stronger stimulus than anodic closure contraction, and the fact is noted K.C.C. > A.C.C. With the electrode on the same motor point, but this time keeping the circuit closed, increase the intensity as before, at the same time occasionally breaking circuit by means of the interrupter. Another contraction soon becomes visible. Again read the galvanometer—perhaps it marks 3 ma. Here the testing electrode being anode and the contraction occurring at opening or break of the circuit, it is an "anodic opening contraction;" and the strength of the current necessary to produce it being 3 ma., A.O.C. = 3 ma. But anodic closure contraction required only 2 ma.; therefore the anodic closure contraction is (in this case) a stronger stimulus than the anodic opening contraction, *i.e.* A.C.C. > A.O.C. (In the case of some nerves A.O.C. appears before A.C.C. Sometimes these two stimuli are of equal strength. The cause of the difference is a physical one and depends perhaps upon polarisation currents, as well as on relative differences in current density, the latter in its turn depending on differences in the nature and bulk of the structures through which the current has to pass on its way to the nerve). Again, having broken circuit but with the testing electrode on the same motor point, put the reversing switch back to normal (marked N. on the element board). This makes the testing electrode once more kathode. Again putting the handle of the cell collector or the rheostat back to zero gradually increase the intensity of the current, and when this has attained a considerable amount, say two, three, or four times the strength of the current in the preceding test, break circuit by means of the interrupter. Perhaps a contraction follows. The galvanometer may mark 10 ma. Here the testing electrode being kathode, and the observation made on opening the circuit, it is a "kathodic opening contraction" (K.O.C.); and as 10 ma. is required to produce it, the fact is noted K.O.C. = 10 ma. If no contraction appear on opening such a cir-

cuit, the latter must not be closed again until the cell collector has been put back to zero, on account of the violent closure contraction that would otherwise ensue. Starting again from zero the current is gradually raised to a higher intensity than before and the experiment of opening the circuit repeated. But in actual practice this process ought not to go on indefinitely. In every electrical examination there is a limit beyond which the intensity of a current should not be pushed. With an electrode so small as that used in electrical exploration, not only does the process become insupportably painful as an intensity of 20 to 25 ma. is approached, but no good purpose is served by it, inasmuch as the violent contraction of neighbouring muscles is apt to mask, and may be mistaken for, the contraction of the muscle under examination.*

Electrical exploration with coil currents.

Passing to the induction coil current ("Faradism") proceed experimentally as before. Having attached the large electrode to the positive pole † (the terminal marked + on the element board) apply it to an indifferent part of the body. The small, or testing electrode being connected to the negative pole, the faradic switch (F.) having been turned on, and the contact breaker of the coil having been put to its slowest rate of vibration (its lowest note), the testing electrode held by its interrupting handle is placed over the motor point of the nerve as before. With the other hand placed upon the secondary winding of the induction coil (the secondary having, to begin with, been quite pulled back from the primary) the secondary is gradually pushed over the primary.‡ Having reached a certain point a muscular contraction appears on closing the circuit, quick and lightening-like as in the case of the galvanic stimulus. The figure on the graduated scale which marks the relative position to each other of the primary and secondary coils is now noted.§

* The contractions produced in electrical testing ought to be "minimal," and, as far as possible, ought not to excite neighbouring muscles.

† Of the secondary wire.

‡ Or a rheostat may be used.

§ The notation on this scale does not afford any definite measurement of

Reviewing the ground that has been gone over, the two following points have been established :

(1) That the normal muscle responds to electrical excitation whether galvanic or faradic, and whether "direct," *i.e.* through the motor point of the muscle, or "indirect," *i.e.* through the nerve trunk, by a short sharp contraction.

(2) With the continuous current the nerve can be excited in four different ways, and to a varying extent. Thus the kathodic closure contraction (K.C.C.) is the strongest stimulus, next comes anodic closing contraction (A.C.C.), or sometimes anodic opening contraction (A.O.C.), and last and long behind the others comes kathodic opening contraction (K.O.C.), which is by far the weakest stimulus.

Normal polar formula.

The law may be formulated thus—

$$\text{KCC} > \text{ACC} > \text{AOC} > \text{KOC}$$
$$\text{KCC} > \text{AOC} > \text{ACC} > \text{KOC}$$
$$\text{KCC} > \text{AOC} = \text{ACC} > \text{KOC}$$

The first of these formulas is the most usual, but we meet both the second and third in normal nerves. This law of normal contraction may, as already explained, be graphically expressed by Fig. 67 (after Hoffman), where the non-shaded parts represent the relative strengths of the muscular contraction.

General considerations bearing upon electro-diagnosis.

When we interrogate the muscles for information about the motor nervous system, in other words, when we bring electrical stimulation to bear upon muscular contractility, comparison must be made with corresponding manifestations in health. In carrying out such investigations the following

the actual strength of the current. The "Faradimeter" is a step in the direction of exact measurements. In this instrument the scale is graduated in volts not in millimètres; and it is sought by means of introducing a galvanometer and resistance into the inducing circuit, to be able to keep the latter constant, and so with a given distance between the primary and secondary always to get the same number of volts from the secondary. Many attempts have also been made in America to measure the intensity and voltage of medical induction coil currents, and with a considerable measure of success; but in the opinion of the present writer it is safe to say that no instrument is yet available for the exact measurements of the currents in question.

points may be borne in mind. (1) Stimulation as has already been pointed out may be "indirect," *i. e.* effected through the nerve trunk, or "direct," *i. e.* through the motor point of the muscle. (2) Even in the latter case there is not, as a rule, a strictly direct excitation of the muscular tissue, but in reality an indirect excitation through the intra-muscular nerve filaments. (3) Electrical stimulation applied to the nerve is not transmitted *as such* to the muscles, but is in the first instance transformed into a *nervous* impulse, and it is the latter which transmitted by the nerve excites the contraction of the muscle. (4) It may be laid down as an axiom in testing neuro-muscular excitability that abnormal reactions are always connected with alterations in the organs examined.

Abnormal reactions.

It has been pointed out by Doumer that the many forms of abnormal electrical reactions which have been described ("reaction of degeneration," "myotonic reaction," "reaction of compression," "reaction of the diathesis of contracture," "reaction of exhaustion") are really combinations or groups of elementary or simple reactions, each of the latter being most frequently independent of one another, and each having its own pathological significance.

The reaction of degeneration ("R.D.").

That *ensemble* of reactions described by Erb, and known as the reaction of degeneration (R.D.), because it occurs when the nerve is degenerated, is the most familiar. In its typical form it consists of (1) abolition of faradic excitability in nerve and muscle; (2) exaggeration of galvanic excitability of muscle; (3) a contraction which is "sluggish;" (4) inversion of the normal formula, *i. e.* K.C.C. becomes less than A.C.C. In other words, R.D. is characterised by the fact that whilst the faradic excitability of the nerve and the faradic excitability of the muscle are similarly affected, the galvanic excitability of the muscle suffers in a way peculiarly its own. To faradism there is loss of excitability in both nerve and muscle; to galvanism there is loss for the nerve, but increased excitability, inversion of the formula and "sluggish contraction" for the muscle. And of all the signs that stamp the true

reaction of degeneration, the most constantly present, the one thing necessary, is the "sluggish contraction."

To follow the course of these changes in their most marked form, consider the case of a nerve cut or bruised; for instance, the ulnar nerve injured in the axilla and stimulated at the elbow:—

Response to faradism.—There may at first be no very apparent change, but in the course of a day or two there is observed a steady diminution of excitability, both in the nerve and the muscle, going on to complete loss, the latter probably occurring about the end of the second week.

Response to galvanism.—Soon after the injury, perhaps in a day or two, there is diminution of galvanic excitability in both nerve and muscle. At about the end of the first, or during the second week, however, instead of a diminution, the excitability of the muscle shows a tendency to become greater than normal, and it may continue to increase to the third or fourth week. Thus the excitability of the nerve growing less and less, and that of the muscle continuing to increase, there has come to be a marked difference in their relative excitability. The nerve probably soon ceases to respond, and on direct stimulation of the muscle, there is noticed "inversion of the formula," *i. e.* K.C.C. is no longer the stronger stimulus (Fig. 69*). Another change also has been developing. Instead of a short, sharp, well-defined contraction, the muscle displays a reaction which is "lazy" or "sluggish." The condition of exalted "galvanic" excitability lasts for a month or so and then suffers a gradual diminution, while the qualitative change, *i. e.* the inversion of the formula and the sluggish contraction remain. If the degenerative changes continue to progress, all contractility disappears, the A.C.C. being the last to go, and the muscle ceases to respond to any stimulus, whether galvanic, or faradic, direct or indirect; excepting by a current parallel to the direction of the fibres (see longitudinal reaction, p. 120). The latter is the last evidence of any excitability remaining in

* And compare with Fig. 67.

a muscle, and this also may eventually disappear. This state of things may be arrived at in weeks or months. If there be

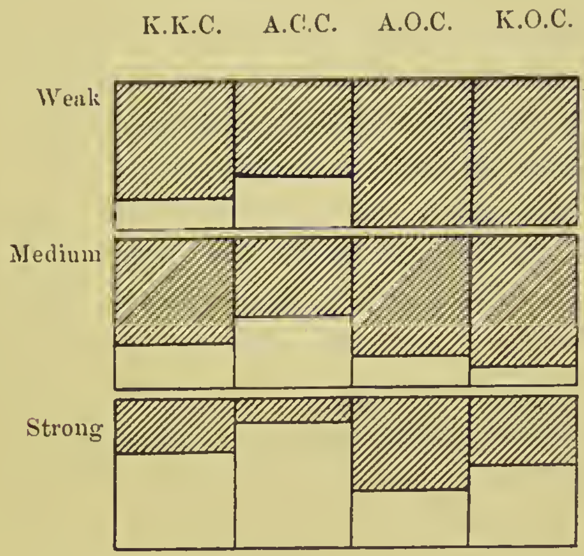


FIG. 69.—Showing "reversal of the formula" in (R.D.).

arrest and regeneration, returning function first shows itself in an approach to restoration of equilibrium between the action of the affected muscles and their antagonists, and by the effects of gravity ceasing to produce deformity owing to the supporting muscles once more being brought into action. Muscular action in response to electrical stimulation appears later.* But the signs of R.D. in the muscle always persist for a time after the return of sensibility in the nerve.

Return of structure and function may occur at various periods, depending upon the surgical progress of the divided nerve. Cases have been recorded where sensation and motor power have been restored in seven or eight weeks. More probably it may be many months or even some years. But no case ought to be given up as hopeless until after two or three years, and not even then if *any* improvement be in progress (Bowlby).*

The different behaviour of the muscle to faradic and

* During the regeneration of a mixed nerve sensibility is restored first, subsequently voluntary motion, and lastly the movements of the muscles when their motor nerves are stimulated directly (Landois and Stirling).

galvanic currents is explained by the variations of E. M. F. in the induced current being too sudden to act on the muscle. But it has been pointed out by d'Arsonval that if a condenser of sufficient capacity be placed in parallel with the secondary of the coil, an arrangement which, as we know, has the effect of lengthening the induction wave, contractions are obtained as with a constant current.

Such is typical R.D. occurring after severe traumatism. But everyone accustomed to electro-diagnosis knows that apart from traumatism, even in degenerative changes accompanied by profound alterations of nervous and muscular tissue, such as occur in neuritis, &c., the abnormalities of response to electrical stimulation are by no means identical with this typical R.D.; and the exceptions are more frequent than the rule.

"Partial R. D."

Thus :—(1) The excitability of the nerve may be not altogether lost, indeed only diminished to a very slight extent; yet the changes in galvanic reactions, *i.e.* the exaggerated excitability, the inversion of the formula and the sluggish contraction may be present.

(2) There may be simple diminution of irritability in both nerve and muscle for coil currents, with sluggish contraction for continuous currents, and without inversion of the formula.

Other anomalous forms are the following :

(*a*) The muscles may respond by a sluggish contraction to stimulation applied through the nerve trunk.

(*b*) The muscle may respond in a similar sluggish manner to coil currents applied through the muscle itself.

Combinations of reactions resolved into simple or elementary reactions.

It is this which has led Doumer, "breaking with the past," to resolve these combinations of reactions into the elementary or simple reactions of which they are composed, with a view to assign to each its own special significance.

These elementary reactions are divisible into two groups. (1) Modifications of excitability to galvanic and faradic stimulation; (2) modifications in the character of the muscular contraction.

1. The modifications of faradic and galvanic excitability are as follows :—

To faradism.—

(*a*) Increase of faradic excitability.

(*b*) Diminution of faradic excitability.

To galvanism.—

(*a*) Increase of galvanic excitability.

(*b*) Diminution of galvanic excitability.

(*c*) Variations in the relative value of K.C. and A.C. (reaction of Erb).

(*d*) Variations in the relative value of K.C. and K.O. (reaction of Rich.).

(*e*) Abolition of all excitability on stimulation through the nerve, but preservation of excitability of the muscular tissue when the latter is stimulated by currents parallel to the direction of the fibres ("longitudinal reaction").

2. Abnormalities in the character of the muscular contraction.

(*a*) Diminution of lost time.

(*b*) Increase of lost time.

(*c*) Diminution in duration of contraction.

(*d*) Increase in duration of contraction.

(*e*) Alterations in the form of the curve.

(*f*) Reaction of exhaustion.

I. Modifications of galvanic and faradic excitability.

Diminution or abolition of faradic excitability is due either to alteration in the motor nerve, or in the corresponding muscle or in both; and indicates some change at the point stimulated, or peripheral to that point, but it tells nothing of lesions situated above that point. This "simple diminution," *i. e.* diminution apart from other abnormalities, may occur in old-standing disease of the nervous centres, or in muscular atrophies, whether myopathic or depending on articular disease.

Diminution of galvanic excitability exists in the same diseases, and has the same significance as diminution of faradic

excitability, but it is especially found in those changes in the motor nerve-trunks that follow traumatism or disease of the anterior cornua. In such cases it means that the motor nerve cells and fibres undergo change of a chronic character. They alter gradually and slowly, and as the number of sound fibres is usually in such cases in excess of those destroyed, no qualitative modification in galvanic excitability is detected. There is similar diminution to both galvanism and faradism. As the number of nervous filaments affected gradually increases, the nutrition of the muscle is slowly and steadily impaired. There is no stage of lost faradic excitability and increased galvanic excitability such as we shall see characterises the R. of degeneration. All that has been said above of diminution of faradic excitability is true of diminished galvanic excitability; and Doumer enunciates the following propositions;

(1) Diminution or abolition of galvanic excitability when present without any qualitative changes, is due to alteration in the nerve or muscle, or both.

(2) It always corresponds to changes having their seat at the point explored, or peripheral to it.

(3) No alteration of the nervous centres or of nerve-trunks above that point can produce it.

Increase of excitability to faradism or galvanism.—The pathological conditions which produce these are very imperfectly known; such increase often precedes degenerative alterations of nerves; and apart from these, increased excitability is found to follow diminished excitability in diseases accompanied by contracture, whether the latter be commencing or established. This increased excitability also occurs in a large number of primary scleroses of the lateral columns.

The foregoing points are thus summed up by Doumer:—Quantitative alterations in galvanic and faradic excitability can give information, only as to the condition of the neuromuscular apparatus at the point of exploration, or peripheral

thereto. But this conclusion is not actually demonstrated excepting in the case of diminished excitability.

The *qualitative* changes of excitability consist in variations more or less marked in the relative value of the various modes of excitation by the galvanic current.

These may be reduced to three groups:

1. Variation in relative intensity of K.C. and A.C. (reaction of Erb).

2. Variation in relative intensity of K.C. and K.O. (reaction of Rich).

3. Disappearance of all "indirect" excitation of the muscle, but existence of "longitudinal reaction."

Alteration in relative value of K.C. and A.C. (R. of Erb).—Wherever this reaction is found there are serious alterations in the histological elements of the nerve, therefore it occurs in severe neuritis from whatever cause, whether traumatic or toxic, in rapid degenerations of the nerve-trunks occurring in acute affections of the anterior cornua of the cord, in progressive muscular atrophies of Aran-Duchenne and Charcot-Marie type, in infantile paralysis, diffuse myelitis involving the anterior cornua, transverse myelitis at the seat of the lesion, etc.

On the other hand, R.D. does *not* occur in the paralysis of cerebral disease, nor in hysterical paralysis, nor in pure myopathies, nor in diseases limited to the white matter of the cord. It is thus evident that one of the chief uses of R.D. is to exclude a certain number of morbid conditions in which it does not occur. It is also clear that this reaction gives more information than any mere quantitative change. The latter leaves in doubt the question whether it is nerve or muscle that is affected. R.D. proclaims that it is the nerve.

The following propositions relative to this inversion of the formula are laid down by Doumer:

(1) The reaction of Erb is symptomatic of an alteration of the nerve-fibre at the point of excitation. This alteration reaches probably the corresponding nerve-cell.

(2) The reaction of Erb is absolutely independent of the condition of the neuro-muscular apparatus situated outside the point of excitation, whether central or peripheral to it.

We have seen that every degree of alteration in electrical excitability may occur, from simple diminution (p. 42) through all the various, partial, and anomalous forms (see p. 41) to inversion of the formula marked and complete. These degrees probably point to the varying number of altered nerve filaments; or it may be that they correspond to different structural changes (parenchymatous neuritis, interstitial neuritis, &c.).

Variations in the relative value of K.C. and K.O. (reaction of Rich) are characterised by the tendency these two reactions have to become equal. It may be seen in R.D., but it is especially apparent in a limb which has been compressed by an Esmarch bandage. In the case of the normal median nerve K.O. requires a current ten times as strong as K.C., whereas in the reaction in question it is 1·25 with K.C. and 1·75 for K.O. The exact pathological signification of this is not known.

Longitudinal reaction ("reaction at a distance").—It is found that although electrical excitability may have disappeared to stimulation at the motor points, the muscle will display a contraction if the direction of the current be made to act parallel to the muscular fibres; and the contraction will be stronger with K.C. than with A.C. (Doumer, Huet, Ghilarducci). This reaction is the last manifestation of contractility before the latter entirely disappears. It is, perhaps, the only case that corresponds to the direct excitation of the muscle (Doumer). But we cannot say that it indicates loss of excitability in the nerve or degeneration in the muscle, although it only seems to be present in cases of such duration as would point to complete destruction of the nerve. It may, however, only mean that a muscle deprived of any nervous influence contracts best when stimulated by a current moving in a direction parallel with its fibres. Under the influence

of curara, which destroys the irritability of the endings of the motor nerves, something very similar occurs.

To elicit this longitudinal reaction the indifferent electrode is placed as usual below the back of the neck, and in the case of long-tendon muscles the active electrode will occupy such positions as the following:

For extensors of wrist and finger: back of forearm a little above wrist.

Flexors of wrist and finger: middle of front of forearm above wrist.

Peronei: behind ext. malleolus.

Ext. l. dig. and Tib. antic.: instep.

Calf muscles: Tendo Achillis near its insertion.

For short tendon muscles:—

Deltoid: back of hand of same side.

Flexors and extensors forearm: front or back of forearm; sometimes back of hand.

Quadriceps fem.: immediately below patella upon the whole upper third of leg; sometimes as low as the instep.

Biceps fem.: half of the calf.

It is with kathodic closure that contraction is strongest in longitudinal reaction. This "reaction at a distance" continues after the disappearance of all others, and this has been explained by the fact that the distance of the electrodes from each other increases the mass of electrolyte between them, and therefore the electrical capacity of the circuit is increased, and the time factor increases with the capacity (capacity $\times$ R. $=$ time). In other words the muscle is traversed by electrical waves *slower* than in the ordinary methods of excitation, hence the stimulus is more effective (Bordier).

II. Modifications in the character of the contraction.

Alterations in the curve of muscular contraction.—It is not sufficient to know whether or not a muscle acts, it is also important to ascertain *how* it acts. The curves or abnormal contractions have been studied by Mendelsohn, who shows that there may be alterations in any of the

various elements of which the curve is composed, *i. e.* in the lost time, in the duration of the contraction, in the amplitude of the curve, in the suddenness of the ascent, and in the line of descent. He gives the following types.

Degenerative Type of Contraction-curve

1. Increase of lost time.
2. Increase of duration of contraction.
3. Slow ascent.
4. Slow descent with undulations in line.
5. Diminution in amplitude.

Found in atrophy depending on degeneration of the nerve.

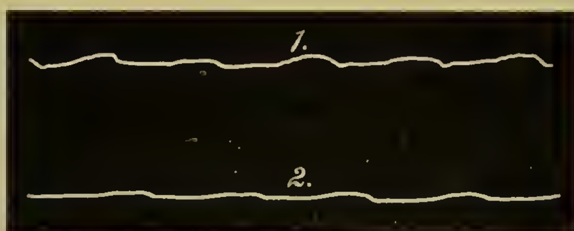


FIG. 70*.—1. Myographic tracing of A.C.C. abd. min. dig.
2. ,, ,, ,, ,, (muscle fatigued).
No reaction to K.C. (R.D. from pressure of a splint).

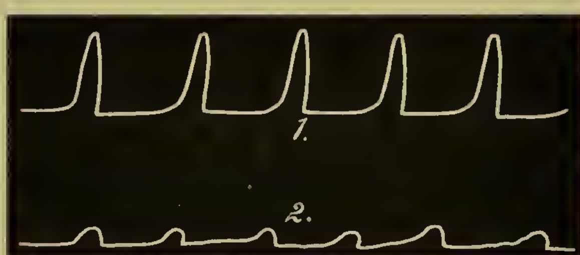


FIG. 71.*—1. Myographic tracing of K.C.C. in corresponding muscle of the other hand.
2. Myographic tracing of A.C.C. in corresponding muscle of the other hand.

Atrophic Type of Curve

As above, but never with undulations in the line of descent.

Occurs in simple atrophies of muscle.

* From Case Books of Electro-therapeutic Department of the London Hospital.

Paralytic Type of Curve

1. Prolongation of lost time.
2. Diminution in height of curve

Occurs in every case of paralysis where there is integrity of the muscular tissue, but where nervous centres are involved.

Spasmodic Type of Curve

1. Diminution of lost time.
2. Brusque ascent.
3. Long descent.
4. Diminished amplitude (in confirmed contracture)

Characteristic of true contracture, whether of sclerosis or contracture.

In the appreciation of these curves the clinical myograph of Radiguet is useful (Fig. 72).

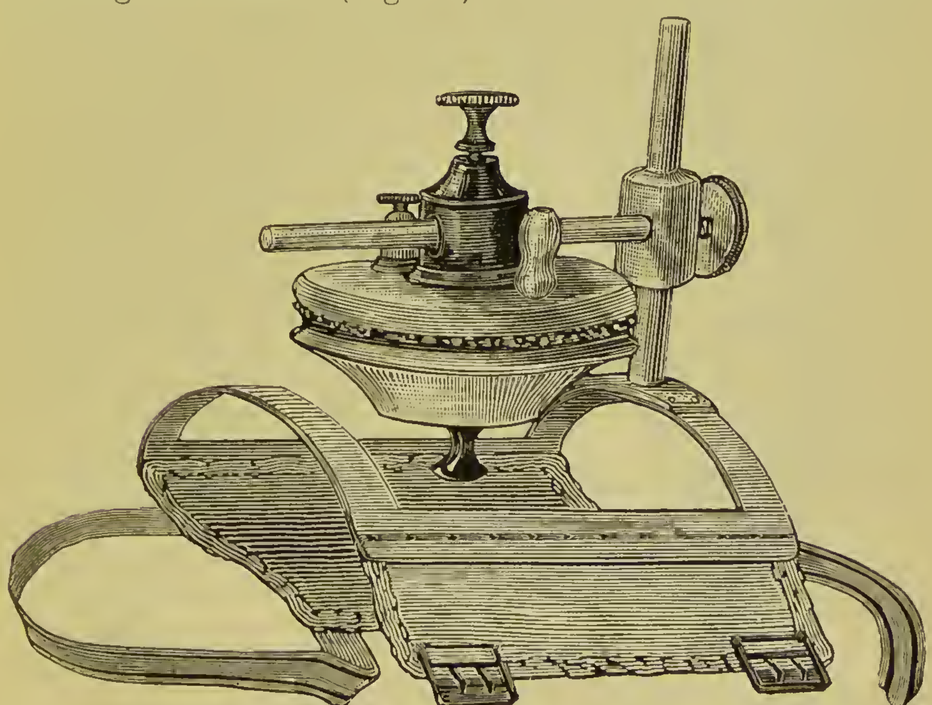


FIG. 72.*—Clinical myograph of Radiguet.

It is important to have a good "form" for noting the

* Showing attachment for tube connecting with recording part of the instrument.

results of electro-diagnosis. That on p. 134 is extracted from the case-book of the London Hospital. Another and less elaborate form is that proposed by M. Mergier, in which the poles are designated by the signs + and −, the initial letter (*c*) of the word contraction being left out. Closing and opening are designated by two symbols, a white circle for opening, a black circle for closing; thus the normal formula, instead of being noted K.C.C., A.C.C., A.O.C., K.O.C., would be written − ●, + ●, + ○, − ○.

Still better perhaps is the graphic method proposed by Prof. Bergonié. Here two lines are drawn at right angles; the horizontal one is the abscissa upon which the current is noted; the relative amounts of the muscular contraction are ordinates. A curve is thus obtained for negative and positive opening and closing, showing for each amount of current the relative extent of the contraction. The curve of the negative pole is marked by the sign −, that of the

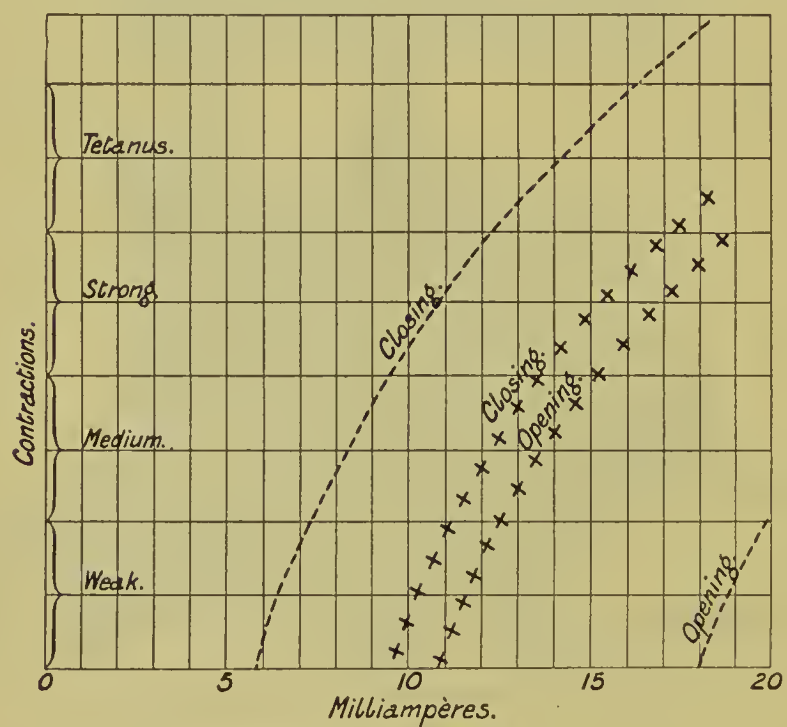


Fig. 73.—Curve expressing the normal law of contraction.

positive pole by the sign +. Thus the normal law of contraction would be objectively expressed by Fig. 73.

Electro-cutaneous sensibility.

Supplementary to the examination of the motor nerves is the investigation of cutaneous sensibility. Lesion of a nerve containing sensory fibres may by interfering with conduction cause loss of sensation over the area of its distribution; but the sensory symptoms do not bear any direct ratio to the loss of motor power; there may be complete muscular paralysis, and sensation be only slightly affected. This occurs too often to admit of its being accounted for by relative differences in injury to the motor and sensory fibres. It must be explained either by the more rapid recovery of the sensory fibres, or because a degree of conducting power that may be sufficient for the stimulation of the sensory centres in the brain may not be adequate to convey a sufficient excitation to the muscles; or it may be that there is a difference in physiological character between sensory and motor impulses.*

It must not be expected that in electrical exploration will be found a means of determining the absolute sensibility of the skin as a sense organ. This must be ascertained by the application of appropriate stimuli.† Electro-diagnosis only offers itself as a means of estimating one kind of sensibility, viz., the sensibility of the skin to an electric current.‡ This form of sensibility may be increased, diminished, or abolished, and seems to correspond most closely to the sensibility to painful impressions.

Normal electro-cutaneous excitability.

The law for the excitation of the sensory nerves is the same as that for the motor nerves. With an electrode 12·75 sq. cm. applied upon the front of the forearm, the following current is necessary to produce sensation:

* Gowers.

† For example, touch by the point of a pencil, or better by a shred of cotton wool drawn lightly over the part, and asking the patient to signify any change in "feeling;" heat by a cautery moved at a definite distance from the skin; cold by a freezing mixture in a test-tube (this, as well as the time-honoured expedient of a hot and cold spoon, becomes complicated with touch and pressure); pain by the "electric finger," &c.

‡ Erb.

Nature of Stimulus.		Current.
K. C.	=	0·9 m.a.
A. C.	=	1·1 „
A. O.	=	1·2 „
K. O.	=	2 „

(Bordier.)

Method of testing electro-cutaneous sensibility.

Until some means of measuring the current of the induction coil is available, the continuous current must be used in this investigation. Electro-cutaneous sensibility may be measured in several ways. The following is one method: Having applied the indifferent electrode (24 square inches) in the usual way, below the neck at the back, take a testing electrode, well padded but flat, and about three-quarters of an inch in diameter attached to the negative pole; then with the circuit kept broken by means of the finger on the interrupter, very gradually diminish the resistance in the rheostat, or put in cells so as to secure a small current; then close the circuit, and ascertain if it is felt by the patient; if not, push back the rheostat to zero, and then, and not until then, open the circuit. Now take more resistance out of the rheostat, or put in more cells, and again close the circuit. If the patient feels it, note the current on the galvanometer. If not felt, push back the rheostat to zero, and commence again with a still stronger current until the first minimal sensation occurs.

For testing the effects of opening the circuit, place the testing electrode on the given region, and increase the current very gradually, then open the circuit, the current being less than 0·1 ma. If nothing is felt reduce the current to zero, again close the circuit, and gradually increase the current until it is stronger than at the first opening. If the patient feels anything note the galvanometer; if he does not feel, continue the process, gradually increasing the current.

Normal electro-cutaneous sensibility varies in different parts of the body. If the first minimal sensation be tested by the application of a measured current, it will be found that the anterior part of the body is more sensitive than the

posterior. In front sensibility is greatest about the face and neck, then come the arms and trunk, and the lower extremity as far as the knee. The foot and leg are last, the heel requiring a current twice as great as any other part. Certain parts, such as the scrotum, the mamma, and wrist have a high degree of sensibility, strictly limited to their own area (Bordier).

Reduced to figures the electro-cutaneous sensibility of various parts of the body comes out as follows:

Temple	0·3 ma.
Shoulder	1·5 „
Forearm (anterior)	1·0 „
„ (posterior)	1·1 „
Hypothenar eminence	1·8 „
Foot (dorsum)	2·0 „
„ (heel)	5·0 „
	(Bordier.)

Here, as in all electrical exploration, care must be taken to secure the same experimental conditions. As already said, the skin over the part examined must be carefully wetted and lightly dried, the electrode must be applied with the same amount of pressure and for the same length of time before the current is turned on, and on the appearance of the minimal sensation the galvanometer must be allowed to come to rest and immediately read.

In cases where the patient's answers are not above suspicion it will be found a useful expedient to test with "the electric finger" and the faradic current. The testing electrode instead of being applied to the patient is held by the operator, and the latter completes the circuit by applying a finger of his other hand to the patient's body. A means is thus secured of gauging the strength of the current, as well as the accuracy of the patient's replies.

Diagrams are added (pp. 128 to 130) showing roughly the topography of the sensory nerves. But it must not be sup-

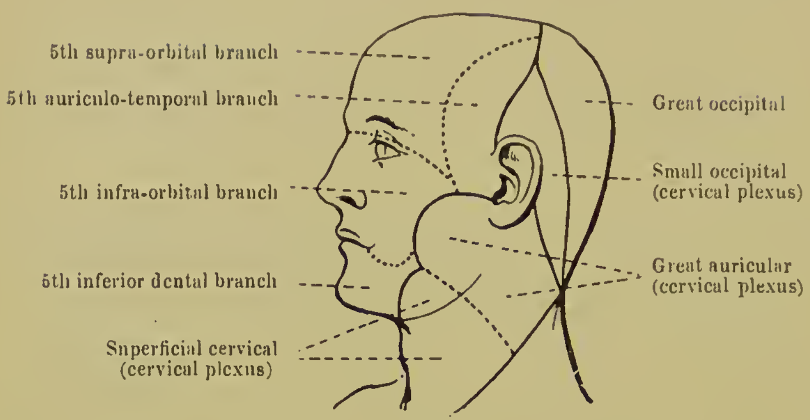

5th supra-orbital branch
5th auriculo-temporal branch
5th infra-orbital branch
5th inferior dental branch
Superficial cervical
(cervical plexus)
Great occipital
Small occipital
(cervical plexus)
Great auricular
(cervical plexus)

Fig. 74.

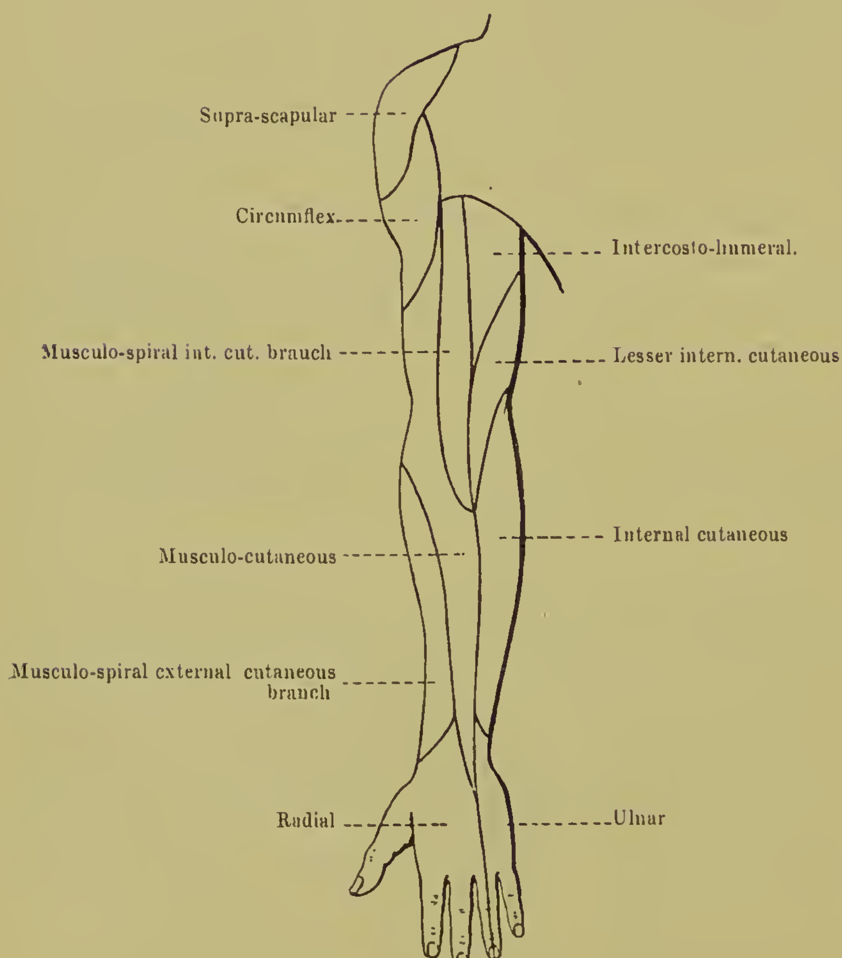

Supra-scapular
Circumflex
Musculo-spiral int. cut. branch
Musculo-cutaneous
Musculo-spiral external cutaneous
branch
Radial
Intercosto-humeral.
Lesser intern. cutaneous
Internal cutaneous
Ulnar

Fig. 75.

posed that each region of distribution is separated from its neighbour by any such clear lines of demarcation. As a matter of fact careful testing will usually disclose an "overlap," *i. e.* a limited region which derives its supply from two contiguous nerves. If, therefore, the function of one of

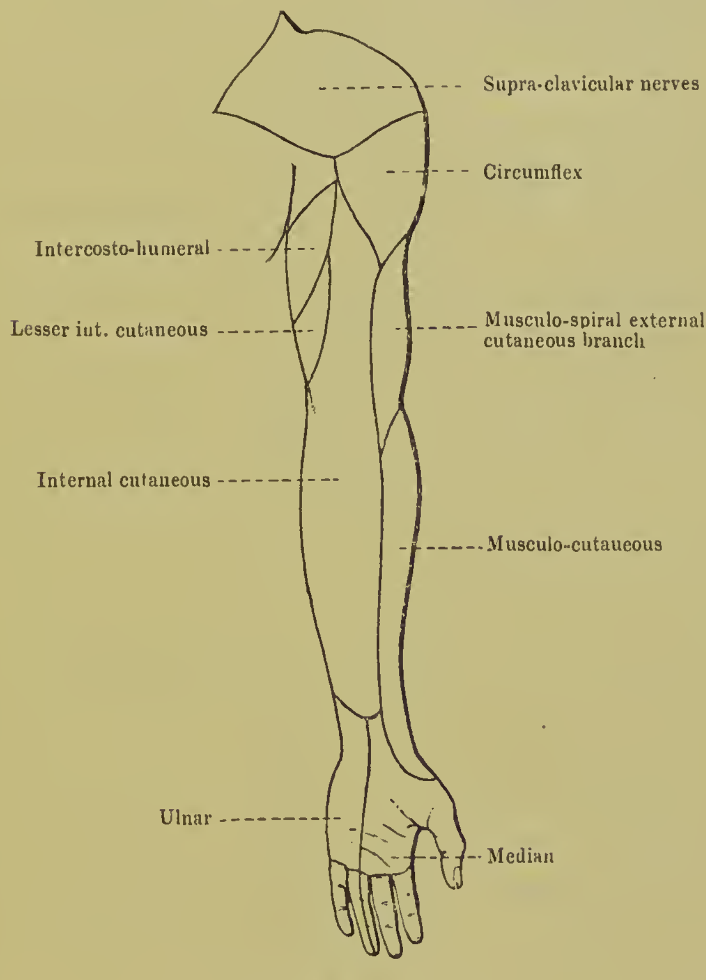


FIG. 76.

them be in abeyance, there is a region of only *diminished* sensibility on the confines of its territory.

The auditory nerve. The auditory nerve responds to electrical stimulation by subjective sensations of sound. The formula is the same as that for the motor nerves, viz. K.C.C. is the strongest stimulus. In some cases of tinnitus the reaction is much stronger than in health. In the examination of the ear it is best to use an

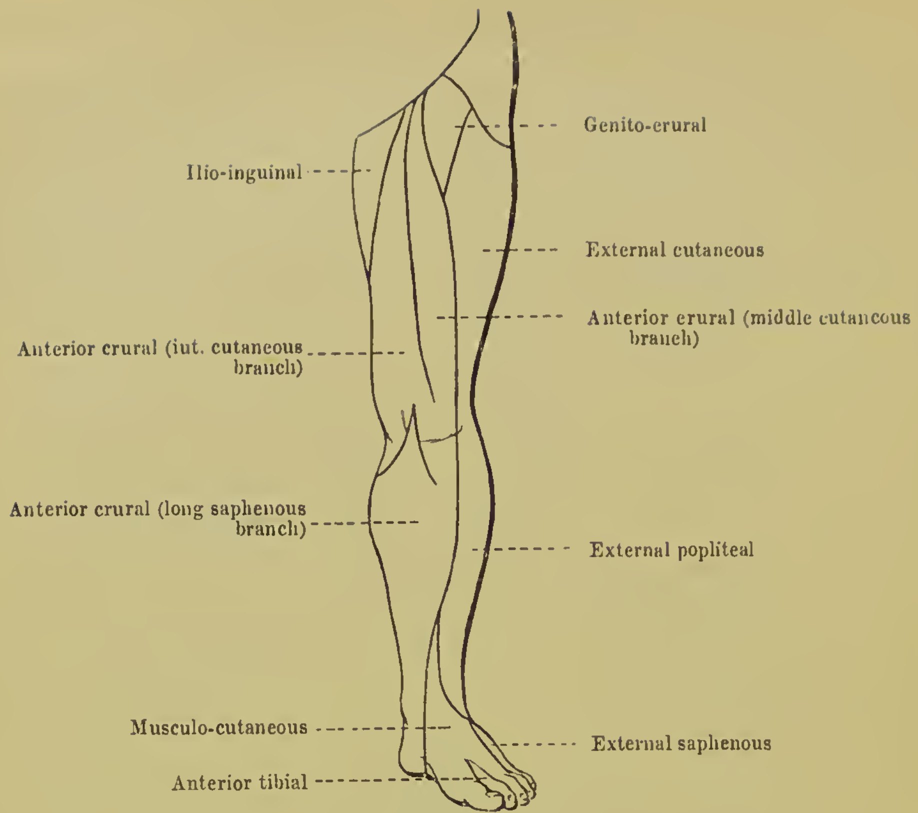

Genito-crural
Ilio-inguinal
External cutaneous
Anterior crural (middle cutaneous branch)
Anterior crural (int. cutaneous branch)
Anterior crural (long saphenous branch)
External popliteal
Musculo-cutaneous
External saphenous
Anterior tibial

Fig. 77.

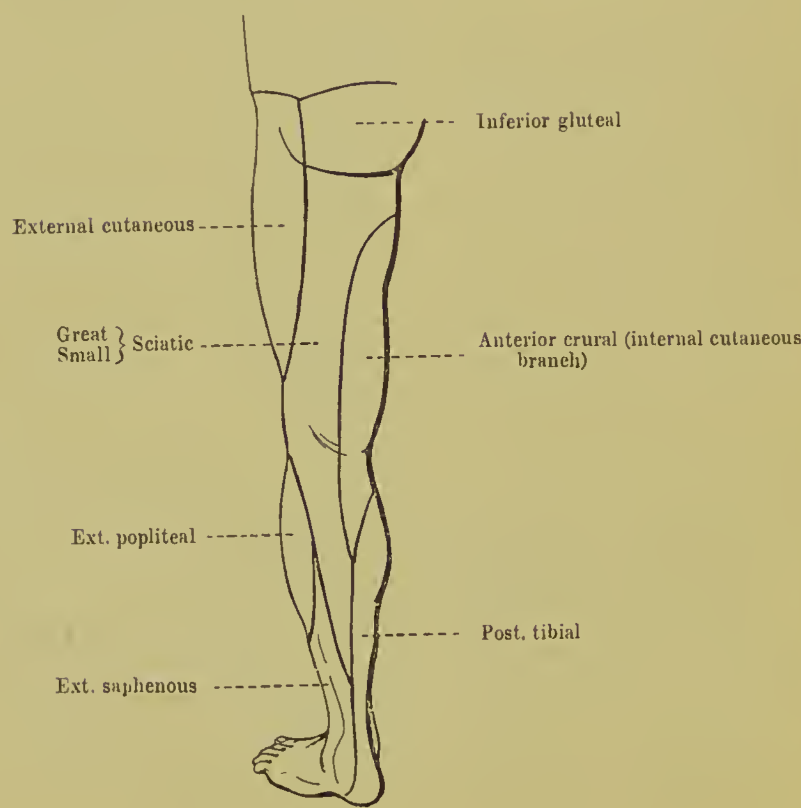

Inferior gluteal
External cutaneous
Great
Small
Sciatic
Anterior crural (internal cutaneous branch)
Ext. popliteal
Post. tibial
Ext. saphenous

Fig. 78.

aural electrode, *i. e.* a divided pole placed just in front of the tragus, the indifferent electrode being placed on some distant point.

Alterations in R. of the body in various morbid conditions.

Attempts have been made to use the electrical resistance of the body as an aid to diagnosis. Thus it has been observed that in some cases of hysteria resistance is increased, and that often in Graves' disease it is diminished. It is stated to be increased in epilepsy, idiocy, melancholia, muscular atrophy (Boccolari, d'Arman, Vigouroux, Silva, and Pescarolo). Dr. Stone states (1886) that resistance is diminished in fevers and in dropsical conditions; others have stated that elevations of temperature are always accompanied by increased resistance. But considering the great difficulties in the way of accurately estimating body resistance, and in view of the fact that body resistance is under the influence of causes so very variable and so little known, it would appear that even if the above opinions could stand the test of experiment such points could scarcely prove of much practical usefulness. Circulation and the functional activity of the nervous system, the general state of nutrition, the greater or less quantity of sodium chloride, are amongst the recognised disturbing causes, and there are doubtless others less well known. Spehl and Sano affirm, as the result of 264 experiments on invalids and others, (1) that the most diverse conditions both in health and in disease may present the same resistance; (2) that whilst certain persons display an absolutely uniform electrical resistance to continuous currents, others, both amongst the healthy and sick, show variations even during the course of the same disease; (3) that the same disease presents different resistances in different persons, and variable resistances in the same person.

R. of the urine.

Dr. Turner considers that much may be learnt by an electrical examination of the urine. He states that the specific R. of a normal urine is about 45 ohms, and "that its R. varies, as a rule, inversely with the specific gravity." The latter is a measure of the amount of solids in solution and

particularly of the urea. But the R. does not depend mainly upon the amount of urea; it depends "almost wholly upon the salts, chlorides, phosphates, sulphates, etc." He considers, therefore, that R. is "a measure of the chemically active substances in a urine,—of the salts, and to a very much less degree of the inert urea."

Electricity in gynæcological diagnosis.

The usefulness of electricity for gynæcological diagnosis is very generally admitted by those who are accustomed to electrical work. It discloses the soundness or otherwise of the uterine appendages, and so points either to a conservative treatment on the one hand, or to surgical interference on the other. If an ovarian pain be hysterical and nothing else, the faradic current will certainly and rapidly diminish it.

The indications furnished by the galvanic current are as follows:

In the case of a uterus which bears a current of 100 m.a. to 150 m.a. without any reaction either during the operation or afterwards, there is no inflammation of the appendages requiring surgical interference. If the uterus is not tolerant of a current of 50 m.a., there is suspicion that the appendages are involved; and this suspicion is seriously strengthened the less the current that can be borne.

In uterine fibromata if the intra-uterine application of the positive pole of the continuous current does not manifestly ameliorate the symptoms, or if it aggravate them, then amongst the possibilities to be considered are fibro-cystic tumour, and malignant degeneration of the fibroid requiring surgical interference.

This kind of investigation is not dangerous, and is only contra-indicated by pregnancy and by recent peritoneal inflammation (Apostoli).

CHAPTER IV

The Motor Points

The topography of the motor points and its ready application to purposes of diagnosis are best studied by following the anatomical distribution of nerves. That is to say, individual nerves are taken and the points ascertained at which electrical stimulation (applied both to the nerve-trunk and to the muscle) most readily induces a contraction.

To gain a general idea of the strength of current ordinarily to be employed in diagnosis the student will in the first instance experiment upon himself, and commencing with the face he will quickly learn that, in this region at least, the use of *mild* currents is highly desirable. It is scarcely necessary to add that the frequent use of very strong currents in testing diseased conditions is much to be deprecated; on the other hand, the mistake must not be made of supposing that a muscle does not answer to electrical stimulation in cases where, as a matter of fact, a stronger current would elicit a response.

The following diagrams fairly well represent the motor points, but it is to be remembered that the latter may vary not only in different individuals, but in the same individual on different sides of the body; and further, inasmuch as electrical exploration has often to deal with pathological conditions which alter the contours of the surface (*e. g.* Bell's paralysis) it is evident that no diagram nor even photograph of the motor points can be uniformly and exactly applicable in every case. In point of fact it is quite possible to exaggerate the importance of such dia-

Report of Electrical Reactions.

Name and Age.—*F. Pincott.* *July 23rd*, 1896.

Muscles.	Continuous Current. (1) Quality of contraction ("Normal" or "Sluggish"). (2) Formula ("Normal" or how altered).	Continuous Current. Excitability.*	Induction Coil. Motor reactions.*	Electro-cutaneous sensibility (state region examined).	Remarks.
Supinator long. R. Ext. c. dig. R. Abd. Pol. l. R. Ext. c. r. l. R. Ext. c. ul. R.	Sluggish contraction A.C.C. > K.C.C.	Diminished	Lost	Diminished back of R. forearm and fingers supplied by radial; in the proportion (in forearm) of (r.) 2, (l.) 5	In railway employ. Ten weeks ago arm fractured by cart-wheel passing over it. Was treated in a country hospital. On removal of splint at end of three or four weeks could not move wrist. Attended that institution six or seven weeks. Was "ordered galvanism, but machine generally out of order." When sent to the London Hospital there was wrist-drop and electrical reactions as in foregoing report. Seeing that the muscles supplied by median and ulnar show unchanged electrical reactions and also the triceps, the injury can be localised in the musc. spiral below the supply of the latter muscle. 5 ma. continuous current passed transversely through the arm at seat of injury for five minutes, followed by labile application of a "mixed" current to the affected muscles, sufficient to induce moderate contractions. Thrice weekly. *Aug. 20th.*—Voluntary power to some extent regained in supin. long. *Sept. 10th.*—Voluntary power to some extent regained in exten. wrist and fingers. *Sept. 30th.*—Recovery nearly complete. To cease attending.
Abd. m. dig. R. Flex. c. ul. R. Interossei dors. R. Flex. sub. dig. R. Triceps R. Flex. l. pol. R. Flex. c. rad. R.	Normal	Normal	Normal		

* "Normal," "Increased," "Diminished," "Lost."

grams. The student of anatomy knows where nerves become superficial, and where therefore they are most easily excitable. He also knows that the motor point of a muscle is the point where the nerve enters; that point is often close to the middle of the muscular fibres in the long direction (Castex).

For methods of recording the results of electrical exploration see pp. 122, 123, 124, and the foregoing report of a case showing the "form" used in the London Hospital.

PLATE I.

FIG. 1.	FIG. 2.	FIG. 3.	*Region of the Facial Nerve.*
A	—	A	Facial nerve, trunk.
B	—	—	,, ,, superior div.
C	—	—	,, ,, middle ,,
D	—	—	,, ,, inferior ,,
E	—	E	Nerve, posterior auricular.
1	—	—	Muscle, froutal portion, occ. front.
2	—	—	,, corrugator supercilii.
3	—	—	,, pyr. nasi.
4	—	—	,, orbicul. palpeb.
5	—	—	,, comp. narium.
6	—	—	,, lev. lab. sup. alæque nasi.
7	—	—	,, lev. lab. sup.
8	—	—	,, zygomatici.
9	—	—	,, buccinator.
10	—	—	,, orbic. oris (common point between the two lips).
11	—	—	,, ,, ,, (half of upper lip).
12	—	—	,, ,, ,, (half of lower lip).
13	—	—	,, lev. menti.
14	—	—	,, depressor lab. infer.
15	—	—	,, ,, ang. oris.
16	—	—	,, platysma myoides.
			Region of Trigeminal (infer. maxillary).
17	—	—	Muscle, temporal.
18	—	—	,, masseter.
19	—	—	,, mylohyoid.
			Region of Hypoglossal Nerve.
20	—	—	Muscle, omohyoid.
21	—	—	,, ,,

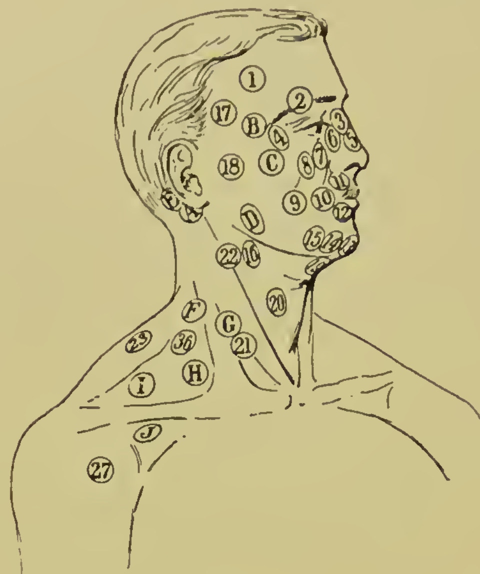


Fig. 1.

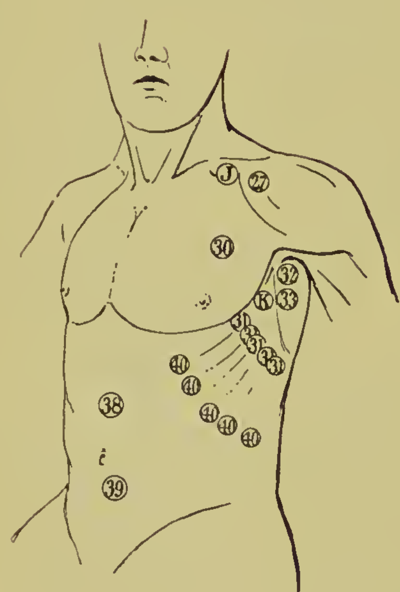


Fig. 2.

Fig. 3.

(Plates I, II, and III are after Castex.)

PLATE I—(*continued*).

Fig. 1.	Fig. 2.	Fig. 3.	*Region of Spinal Accessory Nerve.*
22	—	—	Muscle, sterno-mastoid. C. 2—5 or 6.*
F	—	—	Nerve of the trapezius.
23	—	—	Muscle, trapezius. C. 2—6.
			Region of the Post. Branches, Cervical Nerves.
—	—	24	Muscle, trapezius.
—	—	25	,, ,,
—	—	26	,, splenius.
			Region of Cervical Plexus.
G	—	—	Nerve, phrenic.
			Region of Brachial Plexus.†
H	—	—	Nerve, brachial plexus, Erb's point.‡
I	—	—	,, circumflex.
J	J	—	,, of the pect. maj.
—	K	—	,, of the serr. mag.
27	27	—	Muscle, deltoid, ant. portion } C. 4 and 5.
—	—	28	,, ,, post. ,, } C. 4 and 5.
—	—	29	,, teres minor.
—	30	—	,, pector. maj. C. 5—7.
—	31	—	,, serratus mag. C. 5 and 6.
—	32	—	,, teres major. C. 7.
—	33	—	,, lat. dorsi. C. 7.
—	—	34	,, supra-spinatus. C. 4 and 5.
—	—	35	,, infra-spinatus. ,,
36	—	—	,, lev. ang. scap. C. 3, 4, or 5.
—	—	37	,, rhomboid. C. 4 and 5.
			Region of the Dorsal Nerves.
—	38	—	Muscle, rectus abd.
—	39	—	,, ,, ,,
—	40	—	,, ext. oblique.
—	—	41	,, erector spinæ.

* These letters and numbers refer to the nerve-roots.

† To obtain the best and as far as possible isolated action of muscles, the limb must be relaxed. This is often best effected by the examiner supporting with his left hand the part under examination, so as to suppress all voluntary action on the part of the patient.

‡ "Erb's point" for simultaneous excitation of biceps, brachialis ant. deltoid, supinator longus. About an inch above the clavicle, a little externally to the posterior border of sterno-mastoid, immediately in front of transverse process of sixth cervical vertebra.

PLATE II.

Fig. 1.	Fig. 2.	Fig. 3.	*Region of the Musculo-cutaneous Nerve.*
A	—	—	Nerve, musculo-cutaneous.
1	—	—	Muscle, biceps. C. 4—6.*
2	—	—	,, coraco-brachialis.
3	—	—	,, brach. ant., inner margin.
—	—	4	,, ,, ,, outer margin.†
			Region of the Median Nerve.
B	—	—	Nerve, median, in the arm.
C	—	—	,, ,, at the elbow.
D	D	—	,, ,, in the forearm.
5	—	—	Muscle, pron. radii teres. C. 6 and 7.
6	—	—	,, flex. carpi rad. C. 7 and 8.
7	7	—	,, palm. long.
8	8	—	,, flex. dig. sub. (little and ring) } C. 7 and 8.
9	9	—	,, ,, ,, ,, (index) } C. 7 and 8.
10	—	—	,, ,, ,, ,, (middle) } C. 7 and 8.
11	—	—	,, ,, prop. pol. C. 7 and 8, D. 1.
12	—	—	,, ,, brevis pol. C. 8 and D. 1.
13	—	—	,, abd. pol. b. C. 8 and D. 1.
14	—	—	,, lumbricales (2).‡
			Region of the Ulnar Nerve.
—	E	—	Nerve, ulnar (elbow).
F	F	—	,, ,, (forearm).
—	15	—	Muscle flex. carpi ulnaris. C. 7 and 8.
—	16	—	,, flex. prof. dig. (little and ring).
17	—	—	,, pal. brevis.
18	—	—	,, flex. brevis min. dig.
19	19	—	,, abd. min. dig.
20	—	—	,, add. pol. C. 8 and D. 1.
21	—	—	,, lumbricales (2). C. 8 and D. 1.
—	—	22	,, interossei. C. 8 and D. 1.
			Region of Musculo-spiral Nerve.
—	—	G	Nerve, musculo-spiral.§

* Press testing electrode well under the anterior border of the deltoid and the external border of the coraco-brachialis muscle.

† Press the electrode well in below the biceps, avoiding the median nerve at inner part of arm.

‡ Opponens pol. C. 8 and D. 1. Having found the external border of the first metacarpal bone, push the pointed electrode against the anterior surface of that bone (Roumillac). This and the two previous mm. are difficult to excite independently.

§ Between triceps and brachialis int., just above the supinator long., "at the point where the n. emerges from the triceps." It will often be found easier to excite this nerve independently by means of a continuous current than by means of an alternating one.

Fig. 1.

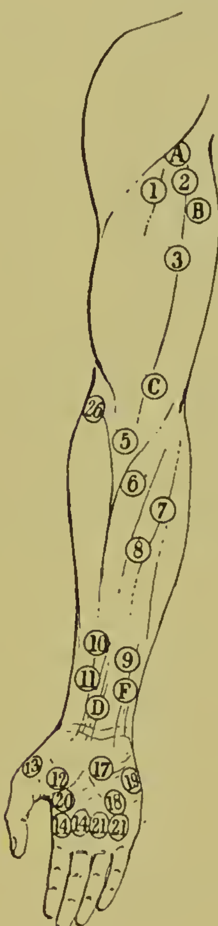


Fig. 2.

Fig. 3.

PLATE II—(*continued*).

Fig. 1.	Fig. 2.	Fig. 3.	
—	23	—	Muscle, triceps. L. head (middle or scapular).
—	24	—	,, ,, Short head (internal or short humeral).
—	—	25	,, ,, External or long humeral head.
26	—	—	,, supinator long.*
—	—	27	,, ext. c. rad. longior. } C. 6 and 7.
—	—	28	,, ,, ,, brevior. } C. 6 and 7.
—	—	29	,, anconeus.
—	—	30	,, supinator brevis. C. 5.†
—	—	31	,, ext. carpi ulnaris.
—	—	32	,, ext. com. digitorum (middle finger). } C. 6 and 7.
—	—	33	,, ext. min. dig. } C. 6 and 7.
—	—	34	,, ext. com. dig. (ring). } C. 6 and 7.
—	—	35	,, ,, ,, (index). } C. 6 and 7.
—	—	36	,, ext. indicis. C. 6 and 7.
—	—	37	,, ext. pol. long. C. 8 and D. 1.
—	—	38	,, abd. long. pol. C. 8 and D. 1.
—	—	39	,, ext. pol. brevis. C. 8 and D. 1.

* To elicit the action of this muscle well, the examiner should support the arm in the semi-flexed position.

† The extensor c. dig. is also excited.

PLATE III.

Fig. 1.	Fig. 2.	Fig. 3.	
			Lumbar Plexus.
			Region of anterior crural nerve.
A	A	—	Nerve, anterior crural.
1	1	—	Muscle, sartorius.
2	2	—	,, rectus. L. 3 and 4.
3	—	—	,, vastus int. L. 3 and 4.
—	4	—	,, ,, externus.
5	—	—	,, pectineus.
			Region of obturator nerve.
6	—	—	Muscle, adductor long. L. 2 and 3.
7	—	—	,, gracilis.
—	—	8	,, adductor magnus. L. 2 and 3.

Fig. 1. Fig. 2. Fig. 3.

			Sacral Plexus.
			Region of superior gluteal.
9	9	—	Muscle, tensor vaginæ femoris.
—	—	10	,, gluteus medius. L. 4 and 5, S. 1.

PLATE III.—(*continued*).

Fig. 1.	Fig. 2.	Fig. 3.	*Region of small sciatic.*
—	—	11	Muscle, gluteus maximus. L. 4 and 5, S. 1.
			Region of great sciatic nerve.
—	—	B	Nerve, sciatic.
—	—	12	Muscle, biceps, long head. } L. 4 and 5, S. 1.
—	—	13	„ „ short „
—	—	14	„ semi-tendinosus. L. 4 and 5, S. 1.
—	—	15	„ semi-membr. L. 4 and 5, S. 1.
—	C	—	Nerve, external popliteal (peroneal).
—	16	—	Muscle, tib. anticus. L. 5 and S. 1.
—	17	—	„ ext. com. dig. L. 5 and S. 1.
—	18	—	„ ext. prop. poll. L. 5 and S. 1.
—	19	—	„ peroneus long. } S. 1 and 2.
—	20	—	„ „ brev.
—	21	—	„ ext. brevis dig.
—	—	D	Nerve, internal popliteal nerve.*
E	—	—	„ posterior tibial.
—	—	22	Muscle, gastrocnemius, ext. head. } L. 5 and S. 1.
—	—	23	„ „ int. „
—	24	24	„ soleus. L. 5 and S. 1.
—	—	25	„ flex. long. pol.
26	—	—	„ flex. long. dig. S. 1 and 2.
27	—	—	„ abductor pol.
—	28	—	„ flex. brev. min. dig.
—	29	—	„ interossei. S. 1 and 2.

* Motor point situated in principal transverse fold of popliteal space.

CHAPTER V

The Action of Muscles and the Consequences of their Paralysis

Any attempt to get exact ideas of voluntary movements by studying the isolated action of muscles, must at best result in comparatively crude conceptions. In every movement that a limb performs, its entire musculature perhaps co-operates, either in synergic or in antergic * action. Further, the mechanical effects of a muscle's contraction must vary with the varying positions of the articulations over which that muscle acts. For example, with the knee-joint bent, the gastrocnemius can no longer produce "plantar flexion" of the foot. Its origin and insertion have been too closely approximated. It has too much "slack" to take in. This is "active insufficiency." Under such conditions it is the soleus alone that pulls upon the tendo Achillis to produce the movement in question. Again, with the knee extended the gastrocnemius is too short to permit complete "dorsal flexion" of the foot. The muscle stretched across the articulation, like a rigid cord, limits the action of the muscles that flex the tarsus upon the leg. This is "passive insufficiency." †

An analysis of the five following positions may be of use in roughly recalling the mechanics of muscular action.‡

* The simultaneous contraction of opponents. "This is synchronous, but not synergic." (Gowers.)

† Landois and Stirling.

‡ In actual testing the resistance would usually be supplied by the hands of the examiner.

Fig. 79.

Latissimus dorsi is in action attempting to force the arm downwards and backwards against resistance from above, at the same time tending to rotate it inwards. The *teres major* assists in both actions. Fig. 79.

(When both *latissimi* act together they extend the trunk. The latter is inclined to one side if only one act. The latissimi are the great propelling muscles in swimming.)

In paralysis of latissimus dorsi forcible backward depression of the raised arm is lost, and the shoulder cannot be put back without being also raised (by the trapezius).*

(The *trapezius* has three parts; an "upper" or respiratory portion, a "middle" and a "lower." The two latter bring the scapula to the spine and put the shoulder back. The scapula and shoulder are elevated chiefly by the middle portion.

The *deltoid* "abducts the humerus, but does not raise the arm higher than to a right angle with the body; the anterior and posterior fibres also move the arm forwards and backwards respectively."†

The *serratus magnus* is in strong contraction, fixing the scapula to the chest and assisting the trapezius (by rotating the scapula) to raise the shoulder above a right angle. ("If the scapula be fixed by the rhomboids, the serratus can act on the ribs and aid forced inspiration.")†

Paralysis of the serratus magnus does not lead to much deformity when the scapula is at rest; but when the arm is moved forward by the anterior fibres of the deltoid, the scapula no longer held in position against the chest by the serratus magnus,† is rotated on its vertical axis by the action of the anterior part of the deltoid on the humerus, and of the middle part on the scapula; the posterior edge, therefore, recedes from the thorax. The characteristic deformity thus produced is shown in Fig. 80.

The *biceps* assisted by *supinator longus* is flexing the

* 'Diseases of the Nervous System' (Gowers).
† Ibid.

elbow, and fixing it by acting (in antagonism) with the triceps.

("The *biceps* first supinates the forearm if it is pronated, then flexes the elbow."*

Fig. 80.

In paralysis the flexion can still be effected by other muscles.)

* Ibid.

The *supinator longus* "places the forearm midway between pronation and supination, and then flexes the elbow."

(The *triceps* acting throughout its three parts extends the elbow.

"In paralysis of the triceps extension against gravity is impossible. A man with paralysis of the triceps cannot raise his hat in the accustomed manner.*")

The *carpal extensors* by fixing the wrist are acting "in co-operative antagonism" to enable the flexing muscles to grasp the cord.

("The *extensor carpi radialis brevior* is a direct extensor, the *extensor carpi radialis longior* and *extensor carpi ulnaris* move the hand laterally as well."*)

(Paralysis of the extensors impairs flexion of the fingers by the too great approximation of the origin and insertion of the flexor muscles. They have too much "slack" to take in.)

The *long flexors of the fingers* (flexor sublimis and flexor profundus) act chiefly on the second and third phalanges.

The *long extensors of the fingers* extend only the proximal phalanx.

The *interossei* fill up the gaps in this flexor-extensor action; that is to say, they flex the first phalanx and extend the last two phalanges. They also adduct and abduct the fingers.

The *lumbricales* "aid the flexor-extensor action of the interossei, but do not move the fingers laterally."*

In paralysis of the interossei the long extensors, no longer opposed, extend the first phalanx permanently, and the long flexors, also unopposed, flex the second and third phalanges, producing the claw-like attitude known as *main en griffe.*

The *pectoralis major* is in action on both sides; its Fig. 81.
upper portion bringing the shoulder forward and tending to raise it, the lower portion attempting to draw each arm to

* Ibid.

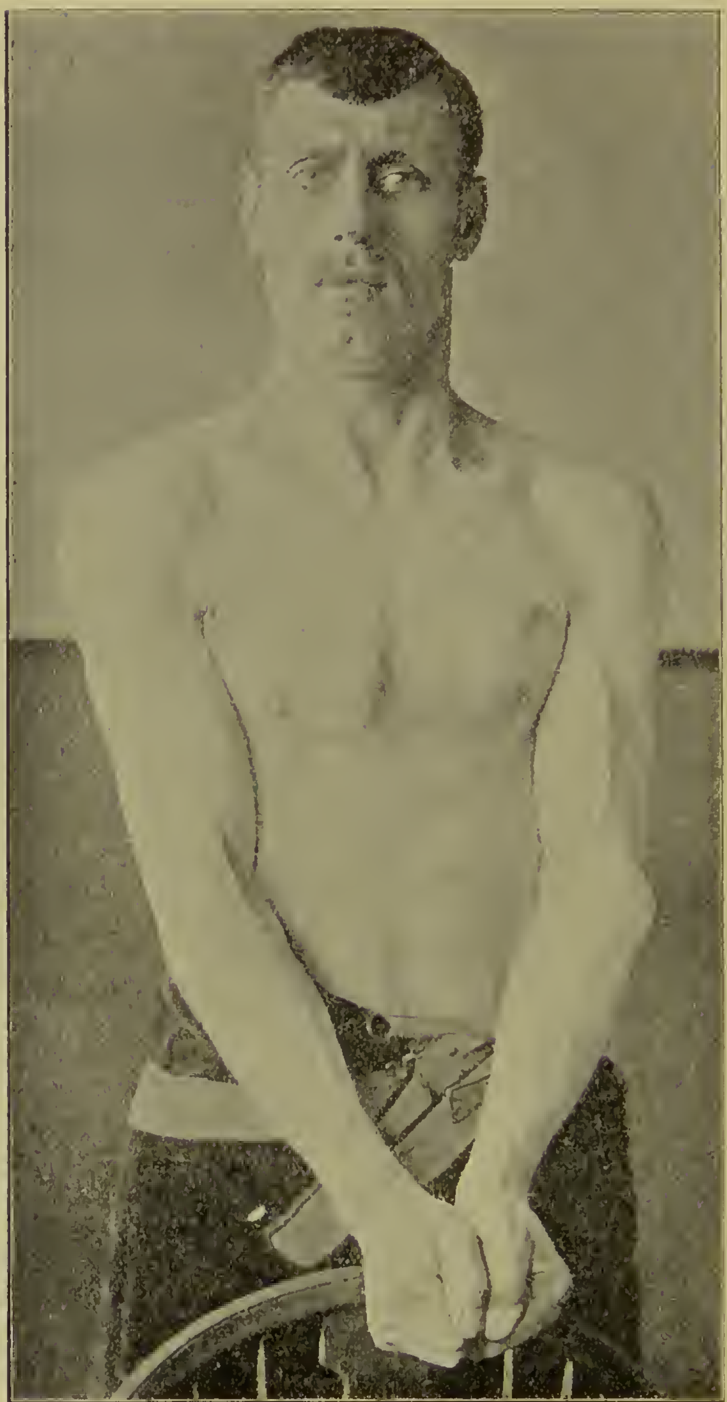


Fig. 81.

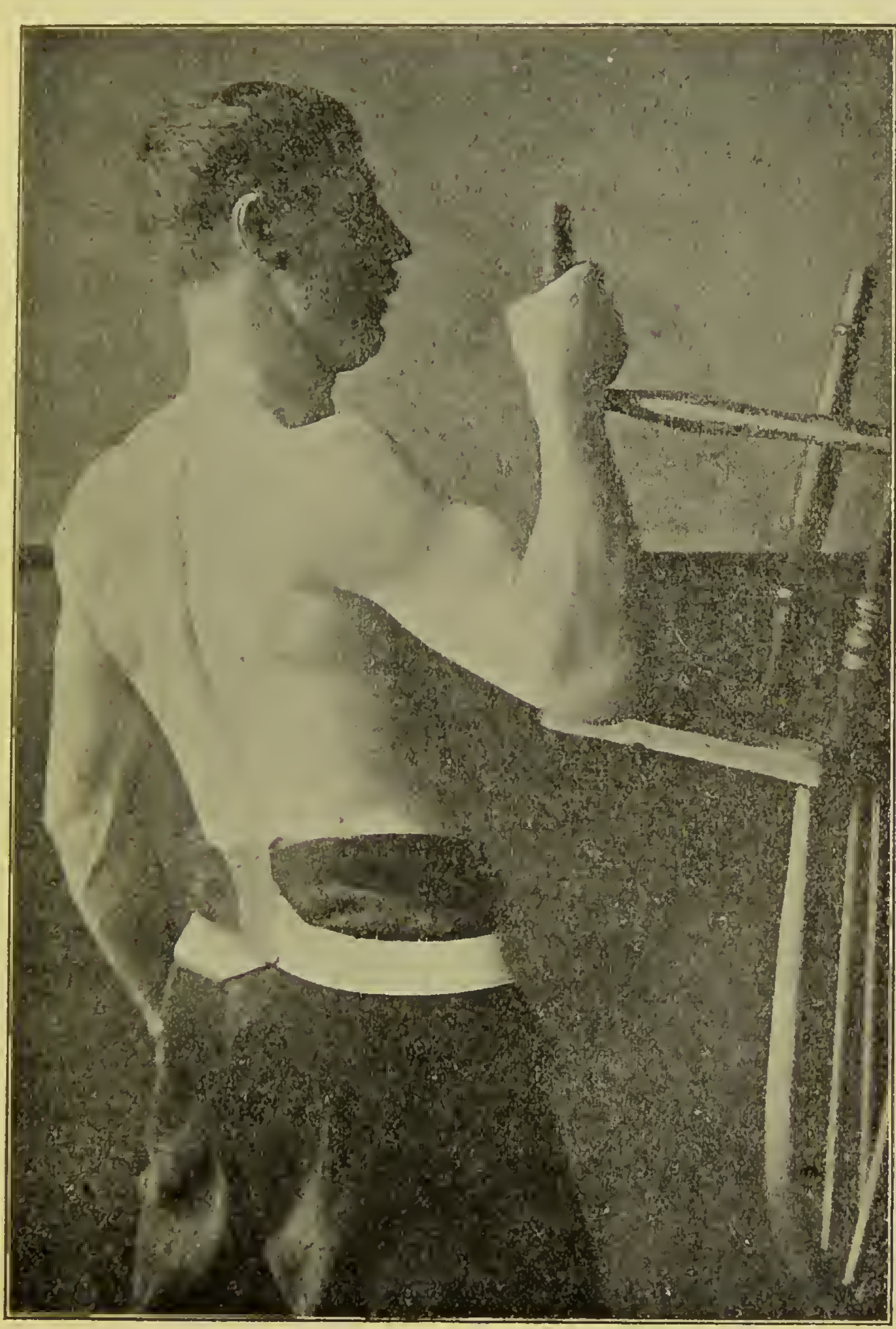


Fig. 82.

the side and across the chest, and at the same time tending to depress the shoulder. By pressing the hands together both arms are brought into action against resistance.

The *sterno-mastoid* inclines the head towards and rotates the head from the side on which the muscle contracts. Both muscles acting together bring the head forward to the vertical position. If they depress the head upon the chest they probably do so by acting upon the neck, the head being fixed.

Paralysis of one muscle has no influence on the position of the head, and but little on its movements. Other muscles supplement the loss. There is no such thing as "paralytic torticollis" (Gowers).

Fig. 82. The arm is raised from the side of the body against the resistance of the weight of the chair by the action of the whole mass of the *deltoid*. The shoulder is elevated by—

Trapezius and *serratus magnus* (rotating the scapula).

The *biceps* and *supinator longus* are flexing the elbow.

The *adductors of the hand* and *carpal extensors* are taking their share in adduction of the hand and fixing the wrist, in co-operative antagonism with the flexors and interossei by the action of which the chair is grasped.

The right side of the body being in action, the head is turned to the same side by the left sterno-mastoid; and it is because the sterno-mastoid associates itself in action with the opposite side of the body that it is called a "contra-lateral muscle."

Fig. 83. The *quadriceps* is extending the knee. (The *rectus* may aid the *psoas* and *iliacus* in flexing the hip, but chiefly when the knee is bent. The *vasti* act only on the knee.)

The *biceps, semitendinosus* and *semimembranosus,* are assisting in fixing the knee. They are flexors of the knee and extensors of the hip in ordinary walking. When a special effort is made the *gluteus maximus* is called into action for extension. The leg is rotated outwards by the biceps, inwards by the semitendinosus.

"In paralysis of the extensors of the knee, standing is still possible if the knee is extended. Rising from the kneeling position is impossible."*

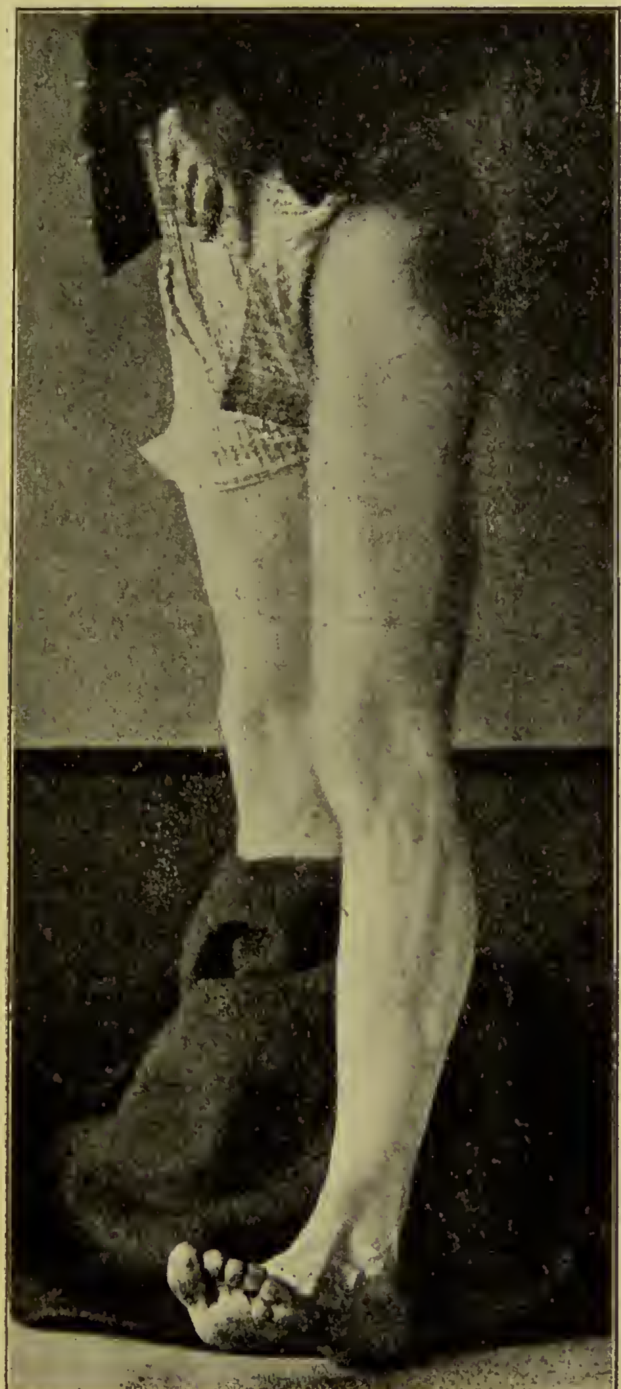


Fig. 83.

* Ibid.

"In paralysis of the knee flexors the loss of power of flexion interferes with walking."*

The *tibialis anticus* and *extensor longus digitorum* flex the ankle. The former of these muscles is also an adductor, and the latter an abductor; acting together they flex the foot.

Paralysis of either "weakens flexion," and the corresponding lateral movement is lost. Secondary contracture of the extensors follows paralysis of the flexors, and *talipes equinus* is the consequence.

The *extensors of the ankle* are the calf muscles * (which also adduct) and peroneus longus (which also abducts).

Adduction and abduction, independently of flexion and extension, are carried out by the tibialis posticus and peroneus brevis respectively. Therefore—

Paralysis of tibialis posticus produces *talipes valgus*, and paralysis of peroneus brevis produces *talipes varus*.

The *gastrocnemius* extends the hinder part of the foot and draws down the outer side. The *soleus* does the same, the only difference being that the latter, "having no attachment to the *femur*, can extend the ankle when the knee is flexed as well as when it is extended." *

The *interossei* act in a way similar to the interossei of the hand.

Of other muscles the action of which is not brought out in the photographs, the following points have to be remembered:

Gluteus maximus extends the hip and rotates the thigh outwards. Is employed in going upstairs or rising from the sitting posture. Not much used in standing, nor in ordinary walking.

Gluteus medius abducts. Its anterior third also moves the thigh forwards and rotates it inwards; the posterior third effects the opposite movements.

In paralysis these movements are lost, and the unopposed action of the external rotators produces a permanent rotation outwards.

* Ibid.

The *pyriformis, gemelli, obturator internus,* and *quadratus* all rotate the thigh outwards.

In paralysis the unopposed action of the internal rotators turns the leg and foot inwards.

The *adductor longus* (and the pectineus) produces an oblique movement forwards and inwards, *i. e.* combined flexion and adduction, as in crossing the legs. It also rotates outwards.

The *adductor magnus* causes a similar adduction and rotation. But it is stated * "that while its upper fibres rotate outwards its lower fibres rotate inwards, and are employed in keeping the foot straight during adduction in riding."

The *innervation* of the muscles is given regionally with the motor points.

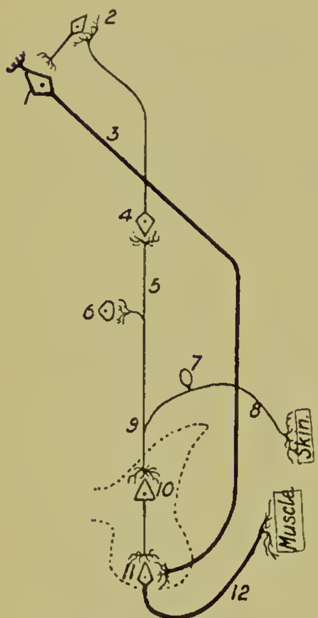
Memoranda

The nervous system is made up of non-continuous elements. The element is called the neuron, and the neuron consists of a cell body with a long process—the axon, and short processes—the dendrons. The axon or axis-process is the chief process. There is usually only one axis-process to a cell, but sometimes two. From the axon there may spring fine fibrils, at right angles to it, termed "collaterals." The axon is made up of a number of fibrils; and it would appear that the terminal divisions into a branching network (arborisation) is merely the separation or splitting up of those fibrils at the periphery, and in the grey matter. To the final twigs of the axon the name of axites may be given (Gowers). The dendrons are the short branching processes of the cell, and they, as well as their branches—the dendrites, soon divide and branch within the grey substance. No essential difference is yet established between the axon and the dendrons. The fibrils of the axon pass through the body of the cell with- The neuron.

* Ibid.

out interruption. Although the fibrils of the dendrons do not all pass to the axon, those of the axon pass to the several dendrons. According to Gowers we must give up the idea that nerve-cells are the seat of the production of nervous impulses or nerve force. External influences act on the minutely separated nerve material at the extremities of the afferent fibrils, and so an ingoing nervous impulse is generated which reaches the centre. Similarly, at the analogous extremities of the fibrils in the grey substance, outgoing impulses originate in their own way. It may be a question whether the cells in the grey matter are the starting-points of nerve force, but there is no doubt whatever that the life of the nerve-fibre, whether axon or dendron, depends upon the integrity of the cell.

Degeneration and its course. According to recent investigation the large cell of the motor area of the cortex (1, Fig. 84) sends down its axis



1. Motor cortex cell.
2. Sensory cortex cell.
3. Pyramidal tract.
4. Posterior column cell.
5. Continuation upwards in posterior median column of upper head of sensory nerve.
6. A collateral.
7. Ganglion in posterior root.
8. Sensory nerve.
9. Division of sensory nerve branching.
10. Posterior column cell and to 5 continuation upwards in posterior median column.
11. Anterior column cell.
12. Motor nerve to muscle.

Fig. 84.—Diagram to explain the constitution of the neurons and the course of secondary degeneration. (After Beevor.)

process through the corona radiata, crus cerebri, and pyramidal tract (3) to an anterior cornua cell (or motor cranial nerve cell), and breaks up into terminal fibrils in the vicinity

of this cell. The anterior cornua cell (or the cranial motor nerve cell) similarly sends out its axon (12), which is continued to the muscle by the anterior root. Thus, when a cortical motor cell is injured the axon degenerates down to its terminal branches. And the result of the lesion of any part of the axis process is degeneration of the part below it as far as the anterior cornua cell, but not involving the latter. If the anterior cornua cell (or cranial motor nerve cell) be affected its axon degenerates down to its termination in the muscles. In the same way in the case of a sensory nerve, lesion of the cell of the ganglion (7) on the posterior root will cause the prolongation of that cell to the skin, *i.e.* the sensory nerve (8) to degenerate as well as its continuation upwards (5) as far as the terminal fibres at the posterior cornua cell (4), and a lesion of the latter (4) will produce ascending degeneration as far as, but not involving, the sensory cortex cell (2). The axis process of the sensory cortex cell (2) splits up into terminal branches at the motor cortical cell (1), and the latter, as already seen, sends its axis process down the pyramidal tract (3), crossing to the opposite lateral column, to end in a network at the anterior cornua cell (11), the anterior cornua cell in its turn sending out its axis process to be continued as the motor nerve to the muscle. Thus, the muscle degenerates in the event of the lesion of the anterior cornua cell (11) or of the prolongation of that cell (12) down to the muscle.

Further light is thrown upon the localisation of various forms of sensation and their disorders by the fact that an axis-cylinder does not conduct as a whole; it is composed of a bundle of conducting paths. The function of the nerve is not limited to conduction; nervous impulses, as already said, take their origin in the minutely divided nerve material at the extremities of the fibrils, whether peripheral or central.

Paralysis.—Loss of power in a muscle may be partial or complete. Paralysis, which is medically applied to every

degree of loss of power, is therefore distinguished as partial or complete.*

The strength of a muscle may usually be roughly tested by the examiner himself opposing its physiological action. With practice any considerable loss of power can thus be gauged with some accuracy, and especially so if a corresponding sound muscle be available for comparison. In doing this it is necessary to remember that the muscular force of the right side is usually greater than that of the left.†

Flexion of the fingers, *i. e.* the "grasp" or "squeeze," may be measured by the dynamometer. The mean of several readings ought to be taken. The "pull" may also be measured.

Muscular sensibility.—The muscles are supplied by sensory nerves, and pain is caused on the application of too strong a stimulus, as in the case of other sensory nerves. When a muscle is made to contract by an electric current the contraction is felt. With a strong stimulus a feeling of deep tension—a "drawn" feeling—is produced amounting to pain. The complication of electro-cutaneous sensibility with this feeling can to some extent be eliminated by anæsthetising the skin; or by making the muscle contract through its nerve trunk, instead of by a direct application to the muscle. The pain is presumably caused by compression on the nerve endings by the muscular contraction. Can electro-muscular sensibility be excited *without* a contraction, *i. e.* by direct stimulation of the sensory nerves? A case combining the absence of muscular contractility on electrical stimulation with complete anæsthesia of the skin would afford an opportunity of demonstrating this point. But it is quite certain that electro-cutaneous and electro-muscular sensibility are distinct. In disease one may be

* The term "paresis" is sometimes used instead of slight paralysis. Kinesis and akinesis are sometimes used to denote movement and loss of movement respectively.

† In the proportion of five to four (Gowers).

absent and the other present. The power of discriminating differences in weight is the recognised test of muscular sensibility. The knowledge which a person has, unaided by other senses, of his own posture, whether active or passive, *i. e.* either when his muscles are active in obedience to the will or only in the "slighter activity" of rest, is ascribed to the "muscular sense," a term which therefore has a more restricted meaning than muscular sensibility.* The latter as above described includes ordinary muscular sensibility to stimuli, and pain when such stimuli are excessive.

Reflex action.—Is effected through an afferent sensory nerve, a centre in which the sensory impression is received and transformed into a motor excitation, and an efferent motor nerve.

For an impression to be *perceived* by the individual a further mechanism is required, viz. an afferent system of sensory fibres, a centre which, more highly organised than the reflex centres of the cord, can recognise the nature of the stimulus, and whence it came; and can originate motor excitations which are transmitted down the cord by an efferent system of fibres to a lower centre of the cord.

There are two chief forms of reflex action :—
(1) cutaneous reflex; (2) muscle reflex.

(1) "Cutaneous reflex"—"superficial reflex," excited by stimulation in the form of stroking the skin adjacent to the muscle tested. The *plantar* reflex is produced by tickling the sole of the foot; this excites slight movement of the toes (through 1st, 2nd, and 3rd sacral). The *gluteal* obtained by stimulating the skin of the gluteal region (4th and 5th lumbar nerve); *cremasteric* by stimulating the skin of the upper and inner part of the thigh, producing retraction of the testicle (1st and 2nd lumbar); *epigastric* by stimulating the skin of the chest over the fifth and sixth intercostal spaces, producing dimpling of epigastrium (4th, 5th, 6th, and 7th dorsal nerves); *scapular* by interscapular stimula-

* See Gowers' 'Diseases of Nervous System,' p. 14.

tion of skin, producing contraction of scapular muscles and those of the posterior fold of the axilla. Of the above reflexes the plantar is the least seldom absent in health. The *conjunctival* reflex and the *contraction of the iris* from slight, and its dilatation from strong stimulation of neck, are also examples of superficial reflexes.

(2) "Muscle reflex"—"tendon reflex"—"deep reflex," excited by "a peculiar mode of stimulation of deeper nerves, probably those only of the muscles" (Gowers). These "reflexes" are produced by the sudden increase of tension in muscles, which are already in a state of slight tension, by striking the tendon or directly extending it.

The patellar tendon reflex or knee-jerk is elicited by flexing the knee "so that the quadriceps is gently extended and the leg free to move," and then suddenly striking the tendon of the patella. The contraction of the quadriceps jerks the knee forward.* The normal knee-jerk depends upon the integrity of the cord at the level of the 2nd and 3rd lumbar nerves, and on the normal condition of the other constituents of the reflex arc.

The physiology of the knee-jerk has been much discussed. Gowers suggests that the passive tension excites in the muscle, by reflex influence, a state of irritability to local mechanical stimulation, such as a sudden tap. It is not stimulation of the nerves of the tendon that induces the contraction, "but the stimulus originates in the muscle." The tendon acts mechanically on the muscle. It is the string, so to speak, which pulls upon the muscle and excites it.

Front tap contraction.—A phenomenon similar to the

* To elicit the knee-jerk it is usual to let the patient sit on the edge of a table with the legs crossed at the knee, the leg to be examined being supported by the other. The knee of the supporting leg is at a right angle; the knee of the leg to be examined is flexed, but not quite to a right angle. The patient is then directed to interlock his fingers and pull in the direction of pulling his hands apart. Voluntary effort is thus taken off the leg. The patellar tendon is then struck with the ulnar border of the hand or with a percussion hammer. There is nothing better for this purpose than the rubber-edged ear-piece of the old stethoscope.

above occurs at the ankle. If the calf muscles are made tense, and the tendo Achillis or muscles on the front of the leg be tapped, a slight extension of the foot is produced.

Ankle-clonus.—In certain pathological conditions, if the ankle is forcibly flexed by pressing the hand against the sole of the foot, a series of clonic contractions occur, known as "ankle-clonus." It depends upon the condition of the cord at the level of the first three sacral nerves, and usually denotes structural changes in the lateral columns.

Radius tap and triceps jerk.—Percussion of the tendons of the flexors and extensors of the wrist, and of the tendon of the triceps, may produce muscular contractions, the former* producing flexion of the elbow, the latter† a contraction of the triceps. In health these are usually feeble or altogether absent.

Diminution in the size of the muscles and alteration in their minute structure follow lesions of the "lower segment" of the motor path. The wasting of a muscle can to some extent be gauged by measurement.‡ The minute changes of structure in the nervous system are referred to in foot-note.§ The changes in electrical reactions which correspond to these have been dealt with under electrical testing.

"Inco-ordination," "ataxy," has been defined as the inability to produce voluntary muscular movement in proper

* *Radius tap*, elicited by striking the styloid process of the radius smartly, the elbow being flexed.

† *Triceps jerk* obtained by flexing the elbow, allowing the forearm to hang vertically downwards, and striking just above the olecranon.

‡ Besides wasting the muscles lose their striation, undergo fatty degeneration with increase of the nuclei of the muscle-sheath, and become pale in appearance.

§ For example, in progressive muscular atrophy of myelopathic origin the lesion will consist of a slow degeneration of the motor cells of the spinal cord and bulb. If the lower segment lesion be a neuritis the nerve-fibres become red and swollen and the myelin disintegrated, the axis-cylinder disappears, and the connective tissue between the fibres increases. Changes are more marked in peripheral than at the more central parts of the nerve. The pain, anæsthesia, and tenderness, as well as the paralysis, wasting, and electrical reactions, are thus accounted for by the above changes in structure.

order or sequence. "It is not customary to apply the term to any derangement of movement except that which is irregular in time. . . . It is necessary to distinguish co-ordination, and the *direction* of movement to a definite end. The motor process for the latter depends on true sensory guidance, chiefly on the senses of touch and sight. A sempstress with loss of sensation in the fingers cannot sew unless she constantly watches them" (Gowers).

Some points about the spinal cord.

Certain practical points in connection with spinal cord anatomy may here be called to mind.

It is customary to speak of "the thirty-one segments of the spinal cord"—a "segment" being that portion of the cord from which a pair of spinal nerves arise. The cord fills only the upper two-thirds of the spinal canal and extends from the foramen magnum to the upper point of the second lumbar spine. The relations of the spines to the vertebral "body" and to the origins of the "nerve-pairs" must be remembered. The "vertebra prominens," *i. e.* the spine of the seventh cervical vertebra, is opposite the first dorsal nerve roots. From the 3rd to 10th dorsal, the spines correspond to the second root below; the 11th spine corresponds to 1st and 2nd lumbar nerves; the 12th to the 3rd, 4th, and 5th; the 1st lumbar to the 1st, 2nd, and 3rd sacral nerves.* The upper part of 2nd lumbar is opposite the tip of the cord. When the spinous process is difficult to feel it is convenient to "follow the last rib to its junction with the vertebra" (Morton).

The lumbo-sacral enlargement begins in front of the tip of the spine of the 10th dorsal vertebra. The cervical enlargement is above the 7th cervical. Each segment comprises in itself a motor, a sensory, and a reflex mechanism, and has a corresponding representation in the periphery. It is largely through the latter that the spinal cord is influenced by electrical and other stimuli.

"*System diseases.*"—This term is applied to those patho-

* Gowers.

logical conditions which attack certain columns of the cord or certain parts of the grey matter, *i. e.* certain "systems" of fibres or cells according to their functions. Poliomyelitis, lateral sclerosis, locomotor ataxy, progressive muscular atrophy, amyotrophic lateral sclerosis, ataxic paraplegia, are instances of these. Their localisation is roughly shown in Fig. 85 (after Peterson). Certain points in the anatomy,

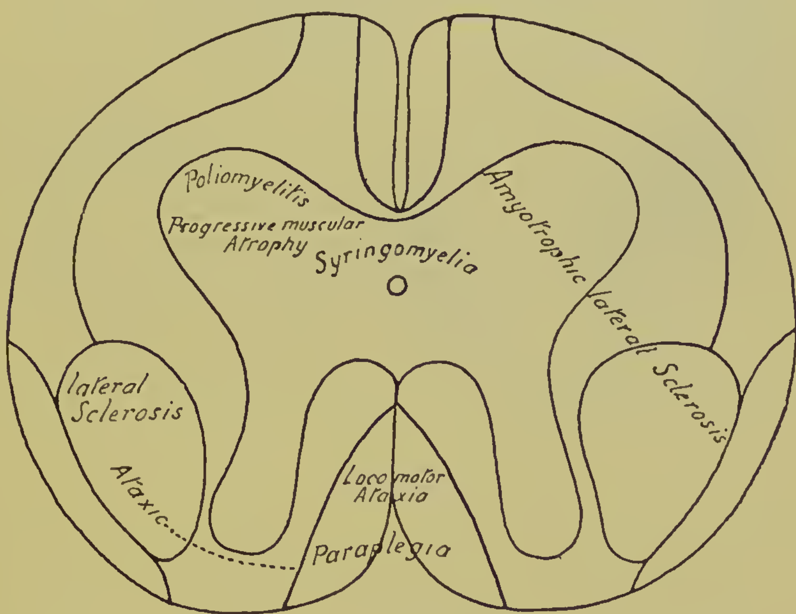


FIG. 85.

physiology, and pathology of the cord are shown in Figs. 86 and 87 (after Peterson).

"Focal" diseases are lesions of limited extent in a particular segment of the cord. Spinal injury, inflammation, hæmorrhages, pressure, tumours, are instances of such, and the symptoms necessarily depend upon the level of the lesion. The distribution of the various reflex, motor, trophic, and sensory functions of the cord is roughly shown in Figs. 88 and 89 (after Peterson).

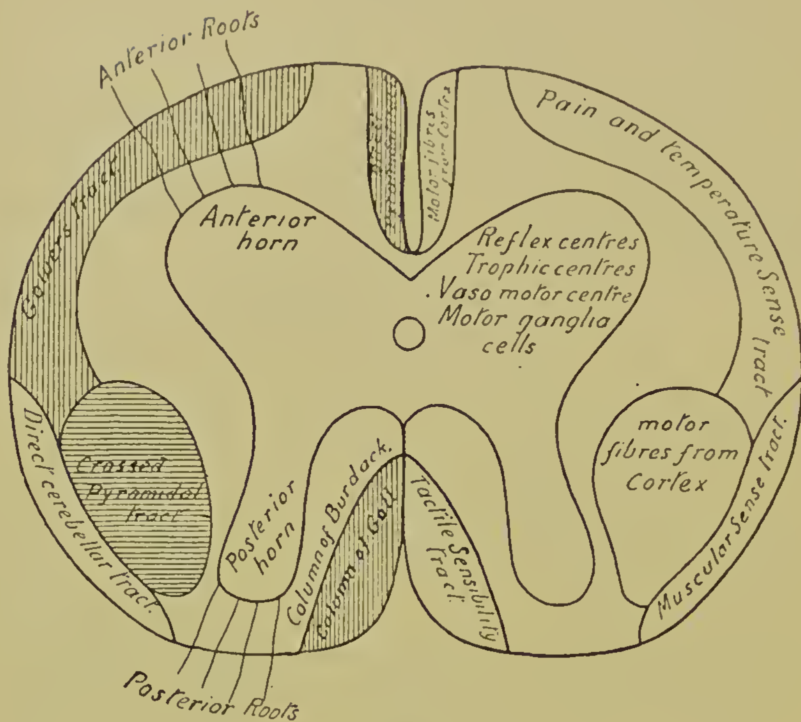

Anterior Roots
Gowers tract
Anterior horn
Pain and temperature Sense tract
Reflex centres
Trophic centres
Vaso motor centre
Motor ganglia cells
Crossed Pyramidal tract
Direct cerebellar tract
Posterior horn
Column of Burdack
Column of Goll
Tactile Sensibility tract
motor fibres from Cortex
Muscular Sense tract
Posterior Roots

FIG. 86.

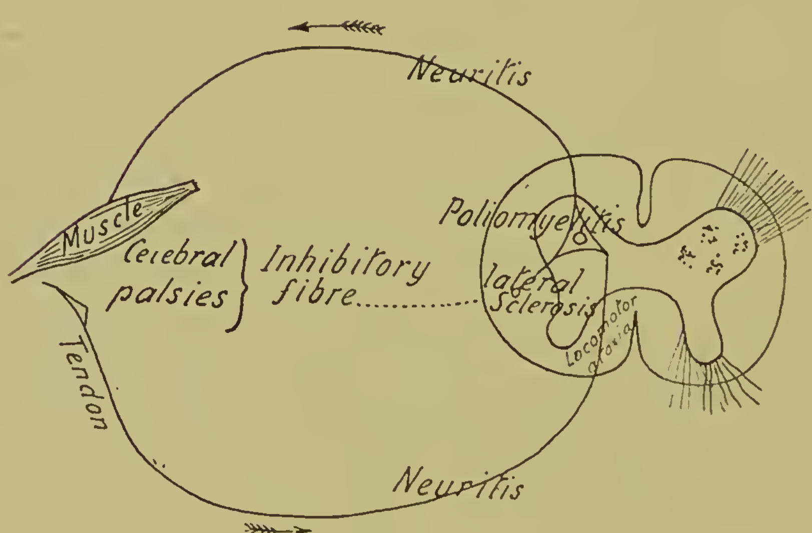
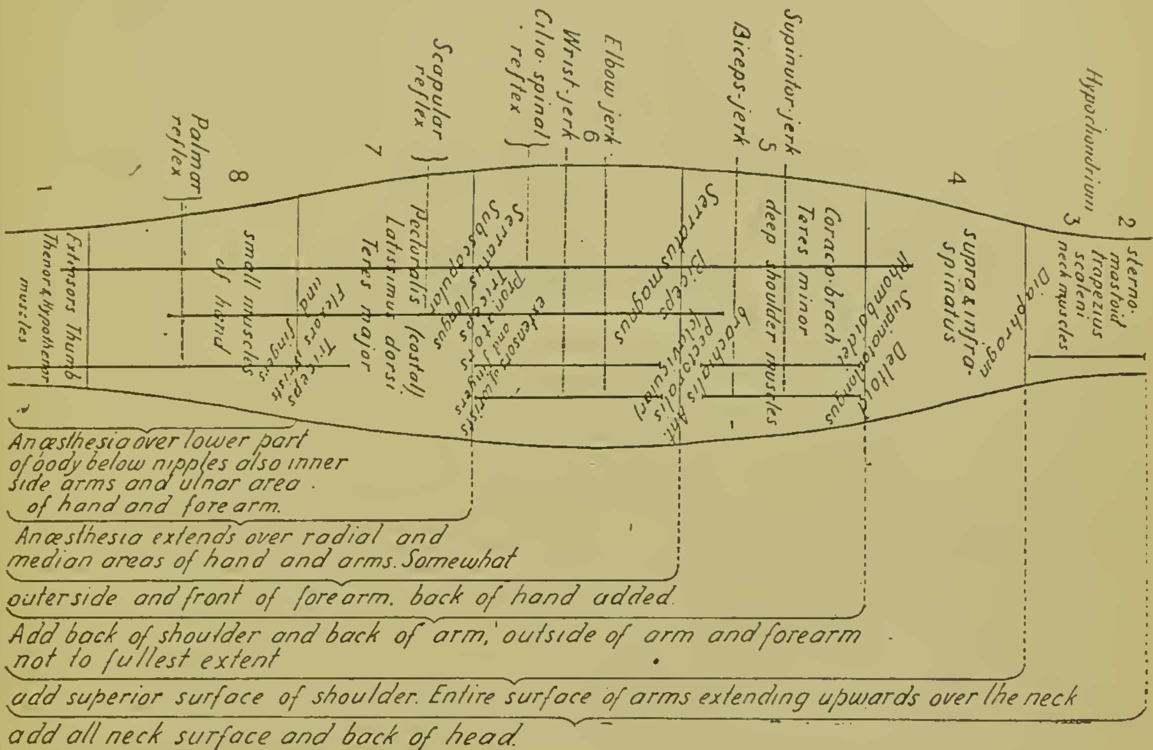
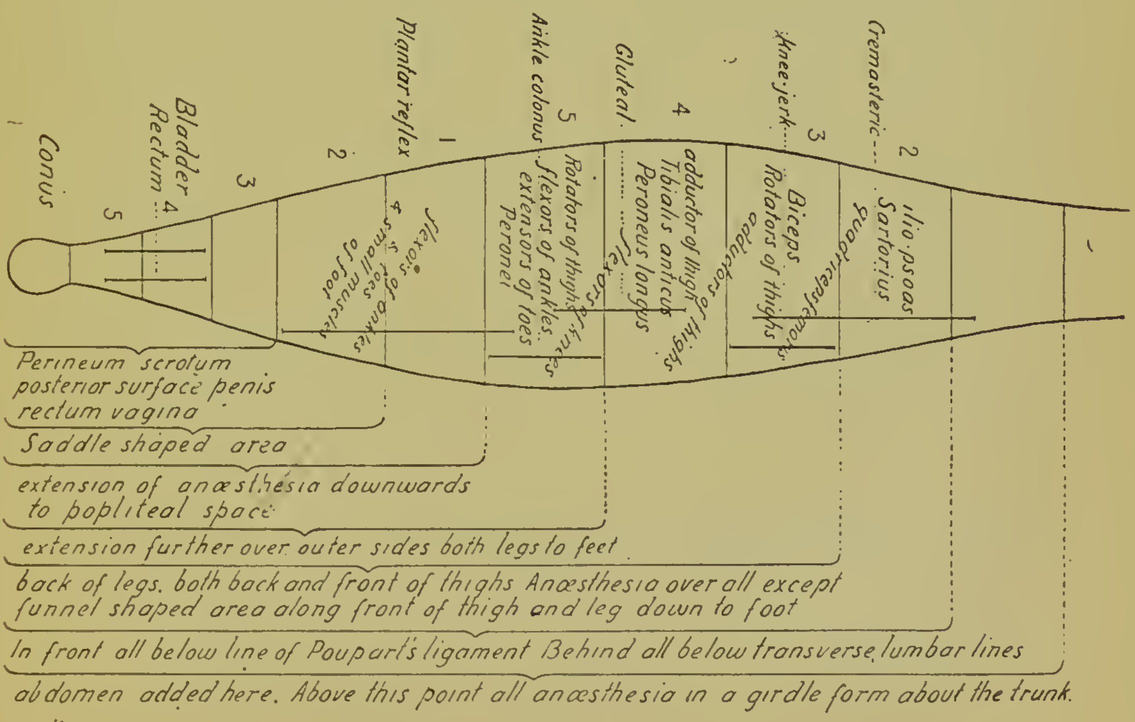

Neuritis
Muscle
Cerebral palsies
Inhibitory fibre
Poliomyelitis
lateral Sclerosis
Locomotor ataxia
Tendon
Neuritis

FIG. 87.



Hypochondrium
sterno-mastoid trapezius scaleni neck muscles
Supra & infra-Spinatus
Coracobrach
Teres minor
deep shoulder muscles
Supinator-jerk
Biceps-jerk
Elbow jerk
Wrist-jerk
Cilio-spinal reflex
Scapular reflex
Pectoralis (costal) Latissimus dorsi Teres major
small muscles of hand
Palmar reflex
Extensors Thumb
Thenar & Hypothenar muscles
Anæsthesia over lower part of body below nipples also inner side arms and ulnar area of hand and forearm.
Anæsthesia extends over radial and median areas of hand and arms. Somewhat
outerside and front of forearm. back of hand added.
Add back of shoulder and back of arm, outside of arm and forearm not to fullest extent
add superior surface of shoulder. Entire surface of arms extending upwards over the neck
add all neck surface and back of head.

FIG. 88.



Conus
Bladder Rectum
Plantar reflex
Ankle colonus
Gluteal
Knee-jerk
Cremasteric
Ilio-psoas Sartorius
Biceps Rotators of thighs
adductor of thigh Tibialis anticus Peroneus longus
Rotators of thighs flexors of ankles extensors of toes Peronei
Perineum scrotum posterior surface penis rectum vagina
Saddle shaped area
extension of anæsthesia downwards to popliteal space
extension further over outer sides both legs to feet
back of legs. both back and front of thighs Anæsthesia over all except funnel shaped area along front of thigh and leg down to foot
In front all below line of Poupart's ligament Behind all below transverse lumbar lines
abdomen added here. Above this point all anæsthesia in a girdle form about the trunk.

FIG. 89.

PART III.

CHAPTER I.

General Electrisation—General Faradisation—Central Galvanisation — Subaural Galvanisation — Galvano-faradisation—Local Treatment of Muscles—Local Treatment of the Spinal Cord—Faradic Brushing and other forms of Cutaneous Excitation.

Before proceeding to deal with the treatment of individual forms of disease it is proposed first to describe the technique of certain procedures which, modified to suit individual cases, present a definite method of dealing with a large proportion of such morbid conditions as are suitable for treatment by electrisation. Recorded as below, these electrical formulæ may appear unnecessarily complex, but if followed out in one or two instances to begin with, they will in the end contribute to clear ideas; and a closer inspection will at once show that no detail therein noted can be overlooked in any electrical application that lays claim to definiteness and accuracy.*

* These formulæ do not imply that electricity can be administered by rule of thumb. The actual "dose" (intensity, density, duration) must be decided at the moment of application, according to the medical and electrical skill of the operator. Electricity cannot be "dispensed."

Abbreviations: + Positive pole. — Negative pole. Current, "continuous," "induced," "combined" (continuous and induced), "sinusoidal;" ma., milli-ampère; sq. in., square inch; sq. cm., square centimetre. "Labile," the electrode moved slowly up and down over the part. "Stabile," remaining stationary.

I. General electrisation.

The methods of general electrisation available in muscular atrophies are static charging (p. 57); the hydro-electric bath * with continuous, induced, or sinusoidal currents; high frequency, high potential currents (p. 64); and the method known as "general faradisation." Of these the last is the only one likely to be within the ordinary resources of the practitioner. It is carried out by placing the patient's feet upon a flat metal plate (kept warm if necessary) attached to the negative pole of an induction coil. The other pole is attached to a circular electrode (three inches in diameter) furnished with a handle, and having a slightly convex surface. This is used "labile" over the various parts of the body in succession. Commencing with the neck, and using a suitable current, the electrode is moved slowly up and down each side of the cervical spine (three minutes), and a few times up and down the anterior border of each sterno-mastoid. The current is then strengthened until capable of producing muscular contraction or just short of this, and the whole length of the spine below the cervical vertebræ is treated in a similar way (four minutes). The breast, abdomen, and extremities are then dealt with (about five minutes), the whole proceeding occupying about twelve to fifteen minutes. But special time and attention may be devoted to special parts and special symptoms, *e. g.* to the abdomen in obstinate constipation. When it is desired to pass a current through the head, this may be done by applying one hand (wetted) to the patient's forehead, and with the other hand *gradually* taking hold of the positive electrode; the current passes *viâ* the body of the operator from the head to the foot of the patient. The looser or firmer hold of the electrode regulates the strength of the current. The duration of the head application may be one minute, and the entire procedure of general faradisation should never exceed fifteen minutes.

II. Central galvanisation.

The object of central galvanisation is to place the whole

* See chapter on hydro-electric methods.

cerebro-spinal axis under the influence of the current. Place a large plate electrode (negative) upon the epigastrium. The operator places his wetted hand upon the forehead, then with the positive pole attached to his other hand he very gradually makes the current by moving the rheostat. A current of not more than 3 ma. is allowed to run for one minute, the hand being slowly rubbed a few times from one end of the forehead to the other; the same is done over the vertex, midway between the ears for one minute. The anode is then passed from one to five minutes up and down each side of the cervical vertebræ and back of the ears and over the course of the cervical sympathetics and pneumogastrics. Finally, the spinal column is rubbed slowly for six minutes along its entire length.

III. Subaural galvanisation.

An attempt is often made (by acting on vaso-motor pathways through the sympathetic?) to influence in a special way the circulation and nutrition of the cord. It is carried out by placing one electrode (generally the negative) 2 × 2 (5 × 5 cm.) "at the angle of the jaw against the hyoid bone, with the surface directed backwards and upwards towards the vertebral column," stabile. The other pole 4·5 × 2 (5 × 12 cm.) is used stabile, and sometimes labile on the opposite side of the neck at the level of the fifth to the seventh cervical vertebræ. The intensity may be 2 to 5 ma., the duration one to three minutes, and if considered advisable the application may be made to both sides. Not only in progressive muscular atrophies, but in various paralyses, spasms, migraine, &c., excellent results are attributable to this method, as all who have systematically used it are able to affirm. How far such results are attributable to the sympathetic is another question; a current following the path indicated must strike many other important structures, such as the medulla, cervical part of cord, and pneumogastric.

IV. Galvano-faradisation.

Galvano-faradisation consists in uniting the galvanic current and the secondary of the induction coil in one

circuit; and in any good battery there ought to be a switch for this purpose. The effects of a faradic current are thus much enhanced, as the point upon which the stimulus falls is in a state of exalted excitability—kalelectrotonus. Wherever faradisation alone is likely to do good, galvano-faradisation is likely to do better. As a rule the strength of the two currents used together may be the same as if used separately.

V. Local treatment to the muscles.

There are several methods available, and the selection will depend upon whether the nutritional and other effects of the current are aimed at, or only muscular contraction pure and simple (electrical gymnastics).

First method.—Current:—

Form, "combined."

Intensity { 6 ma. Coil current just sufficient to produce slight muscular contraction.

Density + ·25 ma. to sq. in.; −1·5 ma. to sq. in.

Duration, 5 minutes.

Electrodes:—

Dimensions + 4 × 6; − 2 × 2.

Position, Polarity, Method } + stabile over spine or upper part of limb; − labile and stabile over muscles.

On alternate days.

(The writer uses a small roller-electrode. In passing this over the muscles slight contractions are secured, and at the same time a useful form of mechanical pressure on the muscle).

Second method.—Place the indifferent electrode on a remote part of the body. The other electrode (of testing-size and having an interrupting handle) is placed over the nerve where the latter is superficial, or over the motor point of the muscle. Then by means of suitably timed interruptions, rhythmical contractions may be induced in individual muscles, or in groups of muscles, either current being used, or both combined. When faradic excitability still remains, this is best done by faradisation, using the rhythmically varying current. Contractions may be thus obtained which are pain-

less, and whose curves accurately resemble those produced by voluntary action.

Third method.—Using the current of the induction coil, the two electrodes held near each other are drawn slowly backwards and forwards over the affected muscles. This is usually what is meant by "electricity" in the crude electrical procedure of the "Weir-Mitchell system."

It is well to remember in the electrisation of diseased muscles (1) that strong currents and powerful contractions are to be avoided, for the obvious reason that they are calculated to exhaust the excitability of a weakened muscle; (2) that muscular fibre ought to be in a slightly relaxed position during electrisation; (3) that it is well to extend treatment to such sound muscles as are likely soon to be attacked.

If a current be localised through an atrophied muscle, it may be expected that not only will the muscle itself be stimulated, but that the sensory nerves traversing its substance will be excited also; and through them the centre in the cord may be indirectly influenced.

VI. Local treatment of the cord.

It is certain that an electric current can be made to traverse the cord, and it is almost certain that such a current can thereby modify circulation, nutrition, and the finer molecular changes of the tissues that lie in its path. It follows, therefore, that so far as the integrity of the cord is concerned, the condition of the latter may be expected to improve. In conditions dependent on lesions of the anterior cornua, it will generally happen that although certain of the ganglion cells are destroyed beyond recovery, there are others whose vitality is only impaired, not lost; and it is easy to conceive of such, that they may be so stimulated and strengthened by electrical treatment (which can certainly reach them) as to be the better able to resist the invasion of the microbe or toxine, or other pathogenic agency that may be at work to threaten their vitality.

A current may be made to pass through the cord (*a*) in a longitudinal (*b*) in a transverse direction.

(*a*) Longitudinal treatment of the cord.

Current :—

Form, continuous.

Intensity, 10 to 20 ma.

Density,* ·4 ma. to sq. in. (·07 ma. to sq. cm.).

Duration 8 to 12 minutes.

Electrodes :—

Dimensions { + 4 × 6 inches — 4 × 6 inches.
10 × 15 cm. 10 × 15 cm.

Position, Polarity, Method } + stabile nape of neck, then labile over spine ; —stabile at base of spine.

On each alternate day.

(*b*) Transverse treatment of the cord.

Current :—

Form, continuous.

Intensity, 10 to 20 ma.

Density + ·37 ma. to sq. in. — ·15 ma. to sq. in.†

Duration, 8 to 12 minutes.

Electrodes :—

Dimensions + 1·5 × 18 in. —7 × 9 in.

Position, Polarity, Method } + on spine, stabile ; — on sternum, stabile.

On alternate days.

VII. Faradic brushing and other forms of cutaneous stimulation.

There is some experimental and much clinical evidence to show that the circulation of the cord and the nerve cells of its grey matter,‡ can be influenced by peripheral excitation. Further, that ingoing impressions arising from the stimula-

* The "density" of a current is the relationship of the intensity of the current to the surface area of the electrode, and may be expressed by a fraction, the numerator of which is the intensity, and the denominator the surface area of the electrode. Thus in the above case $\frac{10}{24}$ = ·4 absolute density, *i. e.* ·4 ma. to the sq. inch, or in centimetres $\frac{10}{150}$ = ·07 ma. to sq. cm.

† To convert inches into centimetres multiply by $\frac{33}{13}$. To convert centimetres into inches multiply by $\frac{13}{33}$.

‡ And probably every structure and organ of the body.

tion of special cutaneous areas* may be brought to bear upon special segments of the cord.

Perhaps every internal organ has its corresponding skin area. In the case of spinal cord diseases this form of excitation is most easily effected by farado-cutaneous brushing. The electric douche is highly effective for the same purpose; its technique is described under Hydro-electric methods.

The treatment of "tender points" may be referred to here. An electrode varying in size with that of the painful area is attached to the positive pole and allowed to remain stabile on the tender point for five to thirty minutes. The current density for such a purpose ought not to exceed, for short applications, 1 ma. per sq. in., and in longer applications may even be so low as ·2.

* Experimentally demonstrated by Hodge. The treatment of such areas by sinapisms and hydro-therapeutic methods are familiar instances of this; and almost equally familiar is the "faradic brushing" of the nape of the neck and spine in neurasthenia, of the lower angle of the scapula in hepatic affections, of the epigastric region in stomach trouble.

CHAPTER II

The Electrotherapeutics of Muscular Atrophies.

Classification.

The field covered by the muscular atrophies is wide and difficult, and by no means fully explored. Yet in looking for a rational treatment it is necessary in the first instance to make a brief survey of some salient points in pathology and classification. In attempting this it may lead to clear ideas, first to define those atrophies which are known as "progressive muscular atrophies," and then to consider others which do not come under such a definition. The progressive muscular atrophies have been described as follows.*

"When a muscle, or a group of muscles, is diminished in volume, and when at the same time there is diminution of the muscular fibre under the microscope, it may be said that there is true muscular atrophy. When the volume of the muscle being preserved or augmented, histological examination shows a diminution of the muscular fibres, at the same time that there is hypertrophy of fatty and cellular tissue, this also is muscular atrophy (pseudo-hypertrophic); when in either case the number of muscles attacked by the atrophy progressively increases, when the affection shows no tendency to regression nor even to localisation, but when group by group the atrophy invades most of the striated muscles of the body, the condition is termed 'progressive muscular atrophy.'"

Accepting this definition and taking advantage of the

* 'Gaz. méd. de Paris.'

classification that accompanies it, muscular atrophies may for present purposes be thus tabulated :—

A. PROGRESSIVE MUSCULAR ATROPHIES.

I. *Myelopathic.*

1. Aran-Duchenne type.
2. Charcot-Marie type.

II. *Myopathic.*

1. Charcot-Duchenne type ("Pseudo-hypertrophic Paralysis").
2. Landouzy-Dejerine type ("Progressive Atrophic Myopathy").

Other less important types are as follows :—

3. Leyden-Möbius type.
4. Erb type.
5. Zimmerlin type.
6. Mixed types.

B. MUSCULAR ATROPHIES, OTHER THAN THOSE KNOWN AS "PROGRESSIVE."

1. Myelopathic atrophies in which the paralysis precedes the atrophy properly so-called, diffuse myelitis, lateral sclerosis, compression of cords, tabes.
2. Glosso-labio-laryngeal paralysis (chronic bulbar paralysis).
3. Amyotrophic lateral sclerosis.
4. Atrophies following lesions of nerves.
5. Atrophic paralysis of deltoid ("rheumatic").
6. Lead palsy.
7. Infantile paralysis.
8. Peripheral neuritis.
9. Atrophies following articular lesions.
10. Syringomyelia.
11. Beri-beri.
12. Anæsthetic leprosy.

Still following for the most part the classification referred to, the foregoing types are broadly differentiated as follows :

A. I. *Myelopathic progressive muscular atrophy.*—Primary, systematised, and progressive disease of anterior cornua; characterised clinically, (*a*) by qualitative modifications of electrical excitability (R.D.), (*b*) by tremors or fibrillary contractions. Two types, Aran-Duchenne and Charcot-Marie.

1. *Aran-Duchenne type.*—A disease of adult life most frequent in males. Heredity and sometimes excessive muscular fatigue seem to be factors in its production. Pathologically it is a pigmentary degeneration or "sclerotic" atrophy beginning in the motor ganglion cells and invading the anterior roots. The muscle undergoes progressive diminution in volume but without fatty degeneration and its structure remains intact. The atrophy is due to the loss of the trophic influence of the motor ganglion cells in the cord.

Symptoms.—This atrophy is not strictly a paralysis, but a diminution in muscular power due to atrophy. The hand is first affected, often the right hand, but the disease soon becomes bilateral. The thenar muscles disappear. The unopposed muscles draw the metacarpal bone outwards and backwards (*main de singe*). Then the interossei (flexors of first phalanx, extensors of the two last) disappear, and the antagonistic muscles being unopposed, the result is extension of the first phalanx, flexion of the two last (*main en griffe*). Later, all the muscles of the hand are so much atrophied that the fleshless hand is like that of a skeleton (*main de squelette*).

It is noticeable that in the forearm the muscles on the anterior aspect are often attacked first. When the shoulder and trunk muscles are attacked, the deltoid atrophies throughout, but the trapezius only at the part supplied by the cervical plexus. Spinal curvature may be induced by these atrophies, and the muscles of the neck may become implicated. At this stage the intact condition of the lower extremities offers a striking contrast to the atrophy that prevails elsewhere. The lower extremities are not as a rule affected,

and only at a late stage of the disease. Respiration and digestion are so far intact, but when the depressor muscles of the lower jaw and the muscles of deglutition and respiration become involved, the condition is of course very grave. There may be temporary arrest in the symptoms, but the course is slowly progressive. It may be a dozen years or so before the respiratory muscles are affected, and the duration of the disease is from one to twenty years. Death will often occur from some inflammatory complication of the respiratory passages when the muscles of inspiration are weakened and atrophied; but the disease itself may be the direct cause of death by asphyxia from atrophy of the diaphragm.

Complications.—Glosso-labio-laryngeal paralysis, œdema, skin eruption, sweating. There may be sensations of cold, but no alteration in cutaneous sensibility.*

Two varieties.—(*a*) Where fatty tissue in the muscles may to some extent mask the atrophy.

(*b*) *Vulpian type* (scapulo-humeral) begins with the muscles of the shoulder and arm, and is a long time before it spreads, and never attacks face muscles.

2. *Charcot-Marie* begins at the feet, attacks in succession legs, arms, hands, and forearm. Extensors suffer more than flexors. Distinctly hereditary, and is accompanied by fibrillary contractions and vaso-motor troubles.

A. II. *Myopathic progressive muscular atrophy* (primitive progressive amyotrophies of Charcot). The feature common to all atrophies of this class is that there is no appreciable alteration of nerves or nerve centres. The myopathy seems to be "primary." They are all hereditary, or at least occur in members of the same family, and in early life. No R.D. No fibrillary contractions.

1. *Charcot-Duchenne type* (pseudo-hypertrophic paralysis). —Disease of infancy or early years. Most frequent in boys. Often several members of a family attacked. There is an *apparent* muscular hypertrophy, at the same time that the

* 'Gaz. méd. de Paris.'

muscular fibre becomes replaced by connective tissue and fat, but the muscular fibre is simply atrophied, and seldom undergoes fatty degeneration; cord and nerve seem to be unaffected.

Symptoms.—Muscular hypertrophy (apparent) generally begins in the muscles of the calf. Almost always progressive, but slow and without rise in temperature. Lasts many years (10 to 20).

2. *Landouzy - Dejerine type* ("progressive myopathic atrophy," "facio-scapulo-humeral"). May appear at any age. Most frequent in boys. As in the foregoing and other pure myopathies, the essential lesion is atrophy of the muscular fibre, simple and primary. No lesion of nerve centres or nerves. Begins with face, attacking first the orbicularis oris and orbicularis palpebrarum. Patient cannot close eyes or mouth. After some years spreads to muscles of upper limbs and trunk. Trapezius rhomboid, deltoid, biceps, brachialis, triceps, sup. long., and ext. c. rad., are generally the only muscles affected for many years.

The forearm retains its muscularity long after the arm muscles are atrophied. Progress slow, and gets steadily worse. Prognosis bad.

Less well marked types of the myopathies are as follows:—

3. *Leyden-Möbius type.*—This follows the course of pseudo-hypertrophic atrophy without the hypertrophic stage. Perhaps a transition form connecting the latter with Erb's type. It commences with the calves, and follows a course irregularly ascending.

4. *Erb's type* ("juvenile").—Begins generally in infancy or about puberty, usually in muscles of shoulder and arm; sometimes it commences in the muscles of the loins and lower extremity; muscles of the forearm remain a long time unaffected (except sup. long.), and muscles of hand scarcely ever attacked.

No R.D. No fibrillary contractions.

5. *Zimmerlin type.*—Closely resembles the last.

6. *Mixed types.*—Combinations and modifications of all the above.

Marie says that "in atrophy the volume of the muscle is nothing, the weakness is everything." Charcot says, "all these types belong to one species, primary progressive amyotrophy." The foregoing definition of "progressive muscular atrophies" distinguishes them from—

B. *Other muscular atrophies.*

1. *Myelopathies distinguishable from progressive muscular atrophies by the fact that the paralysis is the primary and leading feature and precedes the atrophy properly so called.* (Diffuse myelitis, lateral sclerosis, compression of the cord, locomotor ataxy.)

2. *Glosso-labio-laryngeal paralysis* is a *local* progressive atrophy which commencing at the tongue attacks the lips, soft palate, and larynx. Here again the atrophy is *secondary.*

3. *Amyotrophic lateral sclerosis* begins with gradual atrophy of muscles of hands, bulbar symptoms, and exaggeration of reflexes. Afterwards there occurs wasting of muscles of upper limb with rigidity, as well as rigidity of lower limbs, but the latter are often not much wasted.

4. *Atrophies following lesions of nerves.*—The history of an injury to the nerve, the localisation of the atrophy to the distribution of that nerve, the pain and anæsthesia all serve to distinguish such an atrophy from one which would come under the term "progressive."

5. *Atrophic paralysis of deltoid* ("rheumatic") is accompanied by pain.

6. *Lead palsy.*—Characterised primarily by paralysis, and it falls chiefly upon the extensors. Atrophy does not supervene until late. Supinator longus usually escapes.

7. *Infantile paralysis.*—Its course is the reverse of a progressive muscular atrophy. Paralysis complete from the first, but a tendency to spontaneous recovery.

8. *Multiple peripheral neuritis.*—The early paralysis, its

greater incidence on the extensors, the sensory phenomena, the grouping of the muscular lesions which corresponds roughly with the distribution of nerves, the course and progress of the disease, enter into the differential diagnosis.

9. *Atrophies following articular lesions.*—History, localisation at diseased joints without tendency to become generalised, increase of tendon reflexes and other clinical features, distinguish these from progressive muscular atrophy of myopathic origin. To distinguish them from myelopathies there is further the absence of R.D. and of fibrillary contractions.

10. *Syringomyelia* or cavities in the cord. Rarely occurs before puberty. Symptoms begin with some loss of sensation in one hand; may involve both upper limbs and extend to head and trunk; legs may become affected; there is loss of sensibility to heat, cold, and pain, to varying extents; loss to touch exceptional. Often trophic changes in skin; course slow.

11. *Beri-beri.*—A neuritis endemic in East Indies and Japan. Symptoms: numbness and weight in legs, some anæsthesia, weakness in peroneal muscles. R.D. Cardiac branches of vagus apt to become affected. Arms, trunk, diaphragm, and even face muscles may become involved. Two kinds, "moist" and "dry;" due to a specific organism.

12. *Anæsthetic leprosy.*—Occurs in the East and occasionally in Europe. A slow muscular wasting with alterations in electrical reactions; hands and feet especially affected; irregular anæsthetic patches. The lesion is a "fibrous overgrowth" of the sheaths of nerve bundles, and in this the leprosy bacillus has been found. When R.D. is established it results from pressure on the nerve-fibres.

Treatment. In dealing with muscular atrophies, treatment must be directed, not only to the atrophy, but to the lesion, of which the atrophy is the manifestation. For purposes of treatment, therefore, muscular atrophies arrange themselves as follows:

I. Atrophies due to lesions of the cord (*myelopathic*). (Including degenerations consecutive to cerebral disease.)

II. Atrophies due to primary degeneration of muscles (*myopathic*).

III. Atrophies due to lesions of peripheral nerves (*neuropathic*).

I. Myleopathic atrophies.

Progressive muscular atrophy (*myelopathic*).—Local treatment to cord and muscles as detailed above (p. 168). General electrisation and subaural galvanisation are usually indicated in addition.

Amyotrophic lateral sclerosis.—Treatment on the same principles as progressive muscular atrophy, modifications to suit local symptoms.

Myelitis.—Deal with myelitis by treatment directed chiefly to the spine, using only mild currents (3 to 4 ma. at first, later 8 to 10 ma.), and of short duration (one to five minutes). Positive pole stabile to tender points. In myelitis from compression (kyphosis) place the electrodes immediately above and below the curvature, using currents as above (Erb).

Descending secondary degenerations consecutive to "cerebral disease."—Try long-continued action of the positive pole (5 to 8 ma.) with electrodes over the cord stabile; also subaural galvanisation.

Infantile paralysis (*anterior poliomyelitis*).—At least ten days must elapse after the acute onset before commencing electrical treatment. The latter is undertaken with a view of arousing reparative efforts in those ganglion cells whose vitality is not injured beyond repair; also of keeping the muscles exercised until the return of voluntary power when R.D. is complete. Place the affected limb in a basin of warm water at 98° containing the negative electrode. The positive 150 sq. cm. (24 sq. in.) is over the cord or upper part of the affected limb. Eight to 10 ma. is used for five to eight minutes three times a week. Each sitting is terminated by taking the limb from the water bath and stimulating its muscles by a regularly interrupted galvanic current, the

positive electrode being left in its position on the back. If the muscles react to faradism this current may be used to carry out these electrical gymnastics. But under any circumstances they must be of the mildest order.

Locomotor ataxy.—Treatment will follow the lines already sketched out in general methods. But it will be well to use shorter applications (three to five minutes), and milder currents 8 to 10 ma.); adding local treatment directed to the muscles. Special symptomatic treatment, such as the stabile action of the positive pole over the roots of painful nerves and over spots tender on pressure, may also be advisable. Farado-cutaneous brushing of the skin of the back and limbs (method of Rumpf) is an expedient always to be remembered. The hydro-electric bath is, according to the present writer's experience, a most useful measure if medically administered. The ocular and motor troubles, as well as pain, are sometimes improved; and it is possible that the course of the disease may be retarded or temporarily arrested.

Ataxic paraplegia.—A case of this disease occurring in the practice of the present writer, and shown before the Brighton Medico-Chirurgical Society, will illustrate the methods available; and perhaps tend to lessen the scepticism we are so apt to feel as to the possible improvement which may be effected by treatment in certain structural conditions of the cord.

Case.—J. S—, aged 45. The following are notes when case first seen on November 2nd:—"In walking left foot hangs down, and on right side heel comes to the ground first. Giddiness; absolute inability to stand with eyes shut; always falls towards left side. Pupils contract to the stimulus of light. Knee-jerks exaggerated. No R.D. Reels like a drunken man, and has on one occasion come under the notice of the police on account of his unsteady gait in the street. Loss of sensation on left side both for tactile and painful impressions downwards to a point midway been ankle and knee. 'Padded' feeling of sole; tremor in arm in writing."

Treatment.—Galvanism over the cord, using electrodes 150 sq. cm. and a current 15 to 20 ma. ten minutes, followed by faradisation of the

extremities and frequent resort to faradic and galvanic baths; for the latter using 150 ma. Including the baths, the number of sittings amounted to seventy-five, extending over a period of six months. The result was marked amelioration of the symptoms. Patient can walk much better, says he feels a different man, and that (for the first time for fifteen years) he walked the whole length of Western Road without putting a stick to the ground; can close his eyes without falling; sensation restored in legs; padded feeling of feet gone; tremor in arms no longer present. This improvement was maintained when seen a year after. It is evident that the nutritive conditions of the cord had been materially altered and improved.

Friedreich's Disease.—CASE.—Marguerite B—, aged 15. Father alcoholic. Attacked at 8 years of age. Now walks with difficulty. Motor inco-ordination includes upper extremities. Cannot touch nose with finger on being told to do so; cannot pick up pin; nystagmus; embarrassment of speech; absence of reflexes; scoliosis; well nourished. Sister attacked at same age. Treatment commenced September 14th, and consisted of use of continuous current to spine. Negative electrode uppermost; current 10 to 20 ma., fifteen minutes daily. After six weeks great improvement. Could ascend the hospital stairs and walk considerable distance. On December 6th went to hospital alone. On the 13th had not fallen for eight days, whereas formerly she had fallen four or five times a day. Beyond this point improvement did not progress, and there is unfortunately no further history of the patient.

CASE.—Rosalie H—, aged 29. Father alcoholic. Disease commenced at 16 with inco-ordination. On October 29th, 1896, symptoms consisted of nystagmus, involuntary motions of head and body, trouble in balancing, especially with eyes closed, difficulty in speech, loss of reflexes, slight scoliosis. Treatment as in last case current of 20 ma. used. Rapid improvement.

The reporter, Dr. E. Deschamps, concludes that galvanisation is useful in some scleroses of the spine; it ameliorates the inco-ordination and acts, he believes, upon the medullary circulation, thereby furnishing an argument in favour of the hypothesis of vascular sclerosis in Friedreich's disease.

II. Myopathic atrophies.

In the absence of anything like a satisfactory pathology, the methods of general electrisation offer themselves as the most suitable procedures. The use of alternating currents

from the street mains, applied through the water bath, is an excellent way of dealing with these conditions (Gautier and Larat). But whatever form general electrisation may take, there must also be local treatment of the muscles according to one or other of the ways detailed in general methods. Erb (1887) recommends a treatment similar to that used in myelopathic atrophies, inasmuch as, notwithstanding the negative condition of the cord, he considered it by no means disproved that "we have not to do with a trophoneurosis of central origin."

III. "Neuropathic" atrophies and neuritis.

Here, whether the cause be toxic (alcohol, lead, &c.), infectious (diphtheria, &c.), or traumatic we have to deal with alterations in sensibility, motility, and nutrition. In slight cases there may be perhaps only an increase of excitability followed by a diminution; in more severe cases R.D. partial or complete. It is usually considered that electrical treatment deals only with the later lesions produced by the morbid process, and waits until the latter has exhausted itself. Treatment consists of the labile and stabile action of the anode, the other pole being placed on an indifferent part of the body, or preferably (according to Erb) on a more central part of the diseased nerve, or upon the corresponding segment of the cord. The intensity may be 5 to 15 ma., the duration two to ten minutes, the size of electrode 4 × 6 inches. The sitting may terminate with the production of a few muscular contractions (see p. 168). Effects must be carefully watched. For another method see p. 60).

Multiple neuritis.—(Peripheral neuritis. Polyneuritis.) In this case several of the peripheral nerves are symmetrically attacked in rapid succession. The treatment is that indicated above for neuritis in general, but to save time several electrodes of the same size, all attached to the positive pole, may be used, and one placed upon each limb in the way described below for individual nerves. The indifferent electrode being in the usual position below the

back of the neck, and of correspondingly large size. An easier and often more efficient procedure is the hydro-electric bath.

Traumatic neuritis.—There are two forms of neuritis from injury (*a*) a slight form, (*b*) a severe form. In the latter case the severity of the injury produces histological changes, neuritis, and degenerative atrophy. In the slight form the injury is perhaps more of an "irritation;" the reactions are qualitatively normal, and the atrophy is known in the language of electro-diagnosis as "simple atrophy." In the severe form there is R.D. Apart from the severity of the injury, there exists, doubtless, in many cases a predisposition on the part of the patient which acts as the determining factor in producing a degenerative rather than a simple atrophy.

In slight traumatic lesions, such as sleep paralysis, &c., causing only slight changes in the nerve fibres, the direct stabile action of the positive (sometimes negative) pole with an electrode 20 sq. cm., and current of 5 to 15 ma. is usually an effective treatment; especially if this be combined with stimulation of the affected muscles. The indifferent electrode is placed as above described. In degenerative atrophy (and R.D.) following section and severe lesions of nerves, it has usually been considered that some continuity must have been restored before much can be expected from electrical treatment; but there is evidence to show that the latter applied to the seat of lesion is not without influence on the process of repair, and that it may do something more than keep the muscles exercised pending the regeneration of the nerve. A recent experiment of Friedlander (of Wiesbaden) is as follows:—He cut the sciatic nerves of a dog. Daily galvanisation was carried out on the left side, not on the right. At the end of a month the left leg had recovered, and excepting that it became more easily fatigued it appeared as sound as the front legs. The right, on the contrary, was still paralysed, there was ulceration of the

foot and atrophy of the muscles. He concludes that in traumatic paralysis the regeneration of nerve-trunks is hastened by electrisation, and that if employed early it may prevent the occurrence of muscular atrophy.*

Brachial plexus—Erb's paralysis. (Fifth and sixth nerve trunks.) (Fall or blow, or other injury to the neck. Forcible traction. Cold. Injury during operations.)

Place one electrode, 2 × 2 inches, over the lower cervical vertebræ, the other, of rather larger size, in the axilla; use a current of 5 to 10 ma. for five to ten minutes. Then by means of labile applications to the atrophied muscles (faradisation if they react to this) according to one or other of the procedures in general methods, induce slight muscular contractions.

Circumflex nerve.—Its injury results in paralysis and atrophy of deltoid. (Pressure of crutches, falls on shoulder, exposure to cold, rheumatism, dislocations.)

Treatment.—5 to 10 ma., stabile for five to ten minutes through the muscle; then stimulation by labile applications, or interruptions, or faradisation (*see* general methods). Avoid powerful and exhausting contractions. Support the arm horizontally, on the principle of always keeping the muscle relaxed during electrisation.

Musculo-spiral.—Oftener than any other this nerve is paralysed singly. Owing to its course it is liable to injury from fracture of humerus, dislocation, callus, pressure from falling asleep in awkward positions, &c.

Supplying as it does triceps, muscles on back of forearm, integument of same parts, radial side of back of hand, radial side and ball of thumb, ulnar side of thumb, index finger, middle finger, and half of the ring finger, it forms by its wrist drop, limitation to one side, &c., a characteristic paralysis and atrophy, and the incidence of the paralysis on particular muscles usually enables the injury to be accurately localised by electrical and other testing.

* 'Rev. Int. d'Electrothérapie,' 1897.

Treatment.—Continuous current negative pole, 5 to 10 ma., for five to ten minutes over seat of injury, one electrode at front, the other at back of arm. All the affected muscles are then made to contract moderately, and with distinct intervals, by one or other of general methods for three or four minutes. Duration of entire application not more than ten minutes. Every day or every other day.

Ulnar nerve.—Its superficial position at elbow and wrist render it liable to separate injury (pressure, section, neuritis, &c.). Supplying as it does flexor carpi ulnaris, the hypothenar muscles, adductor pollicis, inner head of flexor brevis, all the interossei the two inner lumbricales, and conjointly flexor p. digitorum, all of these may be paralysed or atrophied, involving not only loss of appropriate physiological action, but a characteristic deformity (*main en griffe*), due to paralysis of the interossei and the action of their antagonistic muscles (see p. 147). Treatment to seat of injury as in last case, followed by stimulation of the affected muscles; duration ten minutes. If there be anæsthesia, stimulation by faradic brush from the first.

Median nerve.—When the median nerve alone requires treatment it is generally the result of wounds. In such a case the atrophy falls upon the pronator muscles—pronator rad. teres and pronator quadratus, the flexor carpi radialis, flexor sublimis digitorum, part of flexor profundus digitorum, and thenar muscles excepting adductor pollicis and inner head of flexor brevis pollicis.

Treatment to the nerve and muscles as in the case of the ulnar nerve.

Sciatic nerve.—(Pressure, neuritis, rheumatism, dislocation, &c.)

Taking electrodes 4 × 6, place one over the lumbo-sacral region, and the other below the sacro-sciatic foramen. Let a continuous current (10 to 25 ma.) be used.

Paralysis of the facial nerve.—The well-known signs of paralysis of the muscles of facial expression may occur from

an affection of the nerve (1) between its ramifications in the muscles and the stylo-mastoid foramen; (2) in the temporal bone (disease of the middle ear or neuritis); (3) within the skull (meningitis and tumours); (4) in its passage through the medulla; (5) indirectly by disease of the cortex or internal capsule of the opposite side. The aqueduct of Fallopius is stated to be the commonest seat of rheumatic paralysis and in this case loss of taste in the anterior part of the tongue occurs, from the chorda tympani being involved. In the internal auditory meatus hearing is lost but taste may not be affected. Whether the nerve or its nucleus be affected the result is the same. When its cause is situated above the nucleus, paralysis of the face is no longer "Bell's paralysis" but "cerebral," and often part of a hemiplegia, and may be due to disease of the cortex or internal capsule of the opposite side. In paralysis of the cerebral type the lower part only of the face is affected, the frontalis acting normally, the eyelids are closed almost equally well on the two sides, and elevation of the corners of the mouth is produced when the patient laughs; and for obvious reasons there is absence of R.D.

Prognosis in Bell's paralysis.

If in Bell's paralysis the electrical reactions continue normal it is a slight case and recovery will occur probably in a few weeks. If R.D. be partial, *i. e.* if excitability to faradism be not abolished, recovery may take place in two or three months. If R.D. be complete, three, six, or nine months may be necessary, or recovery may never take place. But these rules are by no means without exception.

Treatment. Method A.

According to one method treatment is as follows: The electrode for the face ought to be as large as possible, so as to embrace the three branches as well as the trunk of the nerve. The large electrode described in the treatment of facial neuralgia will answer this purpose, and by its means a current of 30 to 40 ma. can be employed. After this stabile treatment has been employed for ten

minutes, contractions may be induced in the individual muscles by means of makes and breaks with the testing electrode. The indifferent electrode of very large size (150 sq. cm.) is below the back of the neck. Treatment ought to be three times a week. Powerful contractions by faradism must be avoided, otherwise contracture of the paralysed side may occur.

Those who regard the foregoing method as too heroic will be content to adhere to the conventional method of placing the positive pole of the continuous current just below the mastoid process with a suitable sized electrode, and gently stroking the muscles, according to the direction in which their fibres run, using about 3 milliampères or such a current as does not produce flashes of light in the eyes. This is the usual method and good results have followed its use. **Method B.**

It is noticeable that in cases of Bell's paralysis the patient cannot depress the upper eyelid without first rolling the eye a little upwards and outwards. If he fixes the eye on anything exactly in front or below it he cannot move the upper eyelid. As the cure progresses there is less and less necessity for this upward and outward movement of the eye in attempting to lower the eyelid (Bordier).

Some neurites of toxic or infectious origin.

Alcoholic paralysis.—Treatment, galvanisation of the cord with two large electrodes 150 sq. cm. each, using a current of 30 to 40 ma., the upper electrode being anode. After ten minutes the current is reversed two or three times, but in each case it is reduced to zero before reversal. The current is then used labile over the affected muscles (anode) with frequent interruptions. Cure in general six to eight months with three sittings a week (Bordier). The present writer often avails himself of the hydro-electric bath with continuous interrupted or sinusoidal currents in addition to localised labile galvanisation of the affected muscles.

Lead palsy.—Attacks especially the extensors of the fingers, sparing the anconeus and supinators and sometimes abd. pol. long.; usually begins in the middle and ring

finger, but there are several other forms more rare, *e. g.* the peronei and extensors of the foot may be affected. Treatment by galvanisation stabile and labile over the paralysed muscles as in other peripheral paralyses.

The myalgia of the abdominal wall ("lead colic") produced by lead is rapidly improved by a five to ten minutes' application of faradism, or by Morton currents.

Diphtheritic and other infectious paralyses.—Galvanisation stabile and labile of the affected muscles; and in the more chronic stages galvano-faradisation.

CHAPTER III

The Electro-therapeutics of some Symptomatic Diseases of the Nervous System.—The Electro-therapeutics of Neuralgias, and of Neuroses.

Some symptomatic diseases of the nervous system.

Hemiplegia.—In view of the fact that it is possible to enumerate about fifty morbid conditions in each of which hemiplegia may be a symptom, it is evident that causes must be dealt with as well as the symptoms. Thus cerebral hæmorrhage, cerebral softening, or hysteria, would each require their treatment, electrical and otherwise, in addition to the symptom hemiplegia. Limiting the definition of the latter to paralysis of one half of the body, the result of a lesion on the opposite side of the brain, and taking the commonest case, viz. hæmorrhage about the internal capsule, the treatment, speaking broadly, may be as follows:

Having allowed three or four weeks to elapse since the attack, first use direct galvanisation of the head, the current passing obliquely from the anode on the affected side to the cathode at nape of neck, or sometimes in the opposite direction. Current not more than 2½ ma.; duration one to two minutes. Current to be very gradually made and broken. Then, placing the cathode on the lower part of the affected limb, or placing the latter in water which contains the cathode, the anode is passed up and down the limb for four or five minutes; 6 to 8 ma.; faradisation of the affected limb follows, using such currents as produce only slight contraction for a few minutes; or the two currents can be combined and used together, galvano-faradisation. The aim of treatment must be

to act on the motor neuron central and peripheral. It is usually stated that central galvanisation in such cases has for its aim the production of vascular effects, which promote absorption of the extravasation. It is true that the experiments of Sollier ('Soc. France d'electrotherie,' July, 1895) have thrown doubt on the possibility of appreciably affecting the cerebral circulation by any endurable current; still, it does not therefore follow that the cerebral cells would be in no way influenced. Those who have witnessed the very striking effects of continuous currents passed through the head in cases of insomnia will find it difficult to doubt that the cerebral circulation is really altered by these methods.

Contracture and pseudo-contracture.—These conditions have little in common. In the former muscular structure is unimpaired; it is normal muscle in a state of contraction; in the latter structure is altered, *i. e.* pseudo-contracture is "myogenous with anatomical alterations in the muscle, whilst contracture is myelogenous with physiological alteration of the muscle" (Blocq). A true contracture may pass into a fibro-tendinous retraction (pseudo-contracture). It is usually considered that contracture following hemiplegia points to a descending sclerosis of the pyramidal tracts; or if showing itself (as it rarely does) from the earliest stages of the hemiplegia, it then depends upon intra-ventricular or meningeal hæmorrhage. It is possible, however, that the usual contracture which follows upon hemiplegia may be simply due to the fact that the less paralysed muscles gradually assert a predominance over the more paralysed ones. Thus it is that the flexors are usually the most contracted, being the least paralysed.

It is to be remembered that contracture, besides following hemiplegia, may occur after almost every cerebral lesion, wounds of the head, tumour, meningitis, softening; after sclerosis of the cord, amyotrophic lateral sclerosis, cerebro-spinal meningitis, in neuroses, in hysteria; also from

toxic and infectious causes; and that in addition to local treatment, the treatment of the contracture must be the treatment of the disease. Hysteria is certainly one of the commonest causes; and in this case the condition is to be treated by galvanisation of the spinal cord and labile action of the same current over the contracted muscles. In hysterical anæsthesias and hemiplegias faradic currents are also indicated. Pseudo-contracture may be the result of injury to the muscle, gummata, tumours, inflammatory action, progressive myopathies, &c., and will be treated on general principles and according to the cause.

Tremors.—Tremors affecting hemiplegic limbs are not hopeful cases for treatment. It is best to rely on continuous currents with a predominance of the anode.

Anæsthesia.—The hydro-electric douche, using induction coil currents and the faradic brush over the area affected, are the best form of treatment.

Aphasia.—Here treatment must be the treatment of the producing cause. Motor aphasia might be rationally treated by localising currents over the region of the third left frontal convolution and island of Reil, using the precautions and currents suitable for head treatment already indicated.

Ischæmic paralysis and contracture is a form of paralysis and contracture following fracture of the forearm, described by Volkman,* and termed by him "ischæmic." It is stated that the electrical reactions are not altered, and the condition has been considered to be due to "venous stasis, probably from pressure of narrow splints, and insufficiently padded bandages, especially in the neighbourhood of the wrist," which produce an interstitial inflammation. Owing to "inflammatory fibrosis of the muscles" treatment is unsatisfactory; but it should consist, in a recent case, of forcible stretching under an anæsthetic, of localised electrisation according to one of the foregoing methods, of manipulation and passive movements, and eventually, per-

* 'Centralblatt für Chirurgie,' 1881, No. 51.

haps, tenotomy. When ischæmic claw-hand has existed for some time, cure can scarcely be hoped for. It is not, as was formerly thought, pressure on the nerve which causes the paralysis leading to contracture. The latter is due to "ischæmic muscular shortening." A paralytic contracture would be slower in its onset. The contracture in question may establish itself in a few days.

Neuralgias. It being understood that any localised condition causing or contributing to the neuralgia has been dealt with, one or other of the following electrical methods may be adopted :—(1) Anode of the continuous current, stabile, with low intensities ; (2) continuous current stabile with high intensities ; (3) cataphoresis ; (4) faradic brushing and faradisation with fine wire coil ; (5) electrostatic charging ; (6) hydro-electric bath, with continuous, faradic, or sinusoidal currents. Referring to these in detail—

(1) The stabile action of the anode with currents varying from the fraction of a milliampère to five milliampères, and for a time varying from a few minutes to an hour or more, used according to circumstances three or four times a week, or even several times in the day. The current must be very gradually put on and taken off, and the indifferent electrode placed at some distance from the seat of pain.

(2) Treatment by high intensities. This may be illustrated by a case of tic douloureux. An electrode attached to the positive pole covers the affected side of the face. The indifferent electrode, 400 or 500 sq. cm. is placed on the back. The current is very gradually increased to 35 or even 50 ma., and allowed to run for a quarter of an hour to half an hour. With such currents every precaution must be taken to prevent the possibility of a sudden break in the circuit. Dr. J. Bergonié, who first advocated this method, recommends an electrode of pewter 1 to 2 mm. thick, well insulated at the margins by rubber, and well covered with absorbent gauze 2 cm. thick projecting over the borders. Felt about 1 cm. in thickness may be used instead of the

gauze. All who have used this method carefully must be of opinion that it ought to be fully tried before an operation is resorted to.

Case.—The first case upon which it was used was that of a carpenter under Dr. Bergonié's care, who had suffered for five or six years from crises of extreme severity over the whole of the right side of the face. He had gone through various forms of treatment, had teeth extracted, and taken drugs of every sort. When this treatment was commenced he was never free from pain for more than twenty-four hours at a time; passed whole nights without sleep. He had twelve *séances*, and from the first felt a steady amelioration in the paroxysms. He was seen three years later and had had no return.

(3) *Cataphoresis.*—Various drugs may be thus employed. The following is a case:

Case.—A young lady for several years suffered from left-sided trigeminal neuralgia; attacks recurring every two or three days, and lasting from twelve to twenty-four hours. Morphia hypodermically had become a habit, which she promised to discontinue if the pain could be controlled. Ten drops of a 10 per cent. solution of cocaine, into which was placed half a drop of tincture of aconite, were dropped upon a small piece of blotting-paper and placed over the exit of the superior maxillary. Upon the blotting-paper was placed the anode, cathode being held in left hand. I. 5 ma. for three minutes, increased to 7 ma., then to 10 ma., and continued at the latter for five minutes, when pain was entirely relieved. (Bailey.)

Sciatica, pains of locomotor ataxy, intercostal neuralgia, toothache, and earache have been relieved by a similar method.

(4) *Faradic brushing.*—This vigorously applied is a form of "counter-irritation" which, although painful, is sometimes effective, and in exceptional cases may be tried.

(5) *Static charging.*—After this procedure (see p. 62), carried out by means of a powerful machine, the patient sometimes steps down from the insulating stool quite free from pain. It is sometimes useful to take sparks from the affected part if charging alone is not effective.

(6) *Hydro-electric bath.*—The following case, occurring in

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the practice of the present writer, illustrates the occasional usefulness of this method.

Case.—A man, aged 53, had for about four years suffered from severe paroxysmal neuralgia of second and third divisions of the fifth nerve. Treated by the galvanic anode and administration of Indian hemp. He had remained free from pain for about three months, when it again returned. Medicines of various kinds, including Indian hemp, the removal of teeth, and various forms of electrisation had been tried without success. The patient described the pain as "stabbing," "plunging like knives," "seizing the roots of the tongue." During the paroxysm the face became fixed in spasm, and the man grasped with great force the lower jaw, exercising powerful pressure on the place of exit of the mental branch of the inferior dental. Hydro-electric bath was given, the current being obtained from an alternating light circuit, having a potential of 100 volts and 6000 or 7000 alternations a minute. The effect was striking and immediate. From a condition of intense suffering he found himself, on emerging after an immersion of ten minutes, absolutely free from pain, and he stooped down to tie his boots without any misgiving, a position that a few minutes before would inevitably have produced a paroxysm. Seven baths were given, and the improvement was maintained for several months; but his subsequent history could not be ascertained. In such a case a return of the pain was doubtless to be expected sooner or later.

Trigeminal neuralgia.—See above.

Sciatic neuralgia.—Try first a continuous current stabile, anode 20 by 30 cm., on surface between sacrum and trochanter; cathode, a large plate to foot or calf; * duration half an hour to an hour. Current to be turned on and off very gradually. During first few *séances* current ought to be 15 to 25 ma., after that 8 to 10 ma. The electrodes ought to be so large that no pain is caused by the application. Such treatment is especially useful in cases where massage is painful. The writer has used it with success. The following case illustrates it.

Case.—A. B—, a mechanic, had suffered for several months from sciatica. There was atrophy, the affected leg being 1½ inches smaller than the other. The limb was immoveably flexed. Pressure painful

* Or immersion of these in water containing the cathode.

upon sciatic nerve, especially at point of emergence. Had used a variety of internal remedies, counter-irritation, vapour baths, &c. The above electrical treatment was followed for three months, at the end of which time the patient could resume work, and the atrophy had to a considerable extent disappeared.

Steavenson's method was to apply the cathode labile along the course of the sciatic nerve. Anode on abdomen or on lumbar region, 10 to 20 ma., duration five to ten minutes. Temporary alleviation almost always follows this, and permanent relief is obtained in about half the cases.

The hydro-electric bath is often effective with continuous, faradic, or sinusoidal currents.

Faradic brushing is sometimes useful.

Pelvic neuralgias.—If hysterical, fine wire currents, one electrode above pubis, the other intra-uterine or intra-vaginal; or the intra-uterine bi-polar electrode may be used. Duration ten to twenty minutes. If of neurasthenic origin, use continuous currents upon vertebral column, and anode upon painful spots for ten or twenty minutes. Sinusoidal currents and static treatment are also useful.

Intercostal neuralgia.—One electrode (positive) 100 sq. cm. placed over painful point; the indifferent electrode 150 sq. cm. is placed on the dorsal region. Current 25 to 30 ma. for ten minutes every second day.

Cervico-brachial neuralgia.—Here the positive electrode is applied chiefly to cervical and brachial plexus, the negative, as usual, below the back of the neck. Cataphoresis or any of the methods above enumerated may be had recourse to. Static currents are also recommended (see p. 60).

Epilepsy.—Anode on forehead, cathode nape of neck. Neuroses.
Current 1 to 2½ ma., duration one minute; then anode middle line of head, cathode on occiput, current and duration as above (Erb). Similar treatment is also recommended by Althaus. The present writer has not seen any satisfactory results in epilepsy that could be fairly credited to

electricity; certainly none that will compare with the action of the bromides.

Hysteria.—It is quite certain that many attacks of hysterical paralysis have been cured by electricity; the "electrostatic bath" being the most generally useful. On the first occasion the duration will be five minutes, afterwards fifteen to twenty minutes. Anæsthesias and hemiplegias may be treated by faradisation (see also the treatment of contracture, p. 190). If the hysterical condition be a pure psychosis, the effect may be simply a psychical one; and carrying out the procedure without a current might perhaps be equally effective. But it is just possible that there may be some active molecular condition of the nerves connected with the hysterical condition that is altered by the passage of certain kinds of current. The following extract may explain this:

"In 1889 it was observed by Professor Oliver Lodge that two knobs sufficiently close together could, when a spark passed between them, actually cohere, and, with a single voltaic cell in circuit, conduct 'an ordinary bell-ringing current.' Shortly afterwards M. Edouard Branly* found that a tube of metallic filings enormously diminished its resistance when exposed to the neighbourhood of a Leyden jar or coil sparks. An arrangement of this kind proved to be a sensitive detector of radiation, and such discontinuous conductors came to be called 'coherers.' The cohesion brought about by electrical means could be broken down by mechanical means. Thus sound-vibration or slight taps would restore the contact to its original condition of high resistance.

"In a paper presented to the Académie des Sciences on Dec. 27th last, M. Branly suggests certain points of possible resemblance between coherer action and the conductivity of the nerves for nervous impulses. He points out that in reality there is no very clear line of demarcation between continuous and discontinuous conductors; it is rather a question of degree. Passing from artificial to 'natural' conductors, he argues that the use of the term 'nervous current' since the earliest days of physiological research seems to point to some recognised resemblance between nervous and electrical conduction. Until recently it was thought that the various elements of the nervous system were continuous. Now, since the advent of that trinity in unity known as the neuron, the nervous system may be regarded as composed of

* 'Comptes Rendus,' vol. cxi, p. 785, and vol. cxii, p. 90.

discontinuous elements—*i. e.* of elements contiguous but not continuous. It thus becomes possible to regard the neuron as the counterpart of the metallic granule of certain discontinuous conductors. As a blow will weaken and even abolish the conducting power in the latter, so traumatism may produce anæsthesia and hysterical paralysis—the latter due to a suppression of transmission, sensory or motor, of the nervous influence consequent on a defective contiguity of nerve elements. Again, as the oscillation of electrical discharges establishes the conductivity of discontinuous conductors, so it is known that such discharges act efficiently in the cure of paralysis and hysterical anæsthesia. The possibility, therefore, suggests itself that in both cases the effect is determined by bringing about the contiguity of the elements of the conductor or some modification equivalent to contiguity. The parallelism between the action of a blow and of sparks upon discontinuous conductors and upon the hysterical nervous system may be carried further in the susceptibility common to both of reacting under a feeble stimulus when once a powerful action is produced as a first effect—a condition which M. Branly has referred to in a former note to the Academy as 'sensibilisation par un premier effet' (Dec. 6th, 1897). The high frequency discharges and the electric oscillations which accompany them are especially apt to make discontinuous conductors conduct, and it is such discharges that have been shown by d'Arsonval to have therapeutic effects in the diseases due to perverted nutrition. If the latter affections are of nervous origin, and are due to imperfect transmission of the nervous influence, it is permissible to suggest that electric oscillations act by re-establishing in the nerve a contiguity which had become insufficient. The same writer has recently shown that continuous currents of a sufficient electro-motive force produce in discontinuous conductors the same effects as discharges at a distance. It would be interesting, he suggests, to inquire if the mode of action of continuous currents in diseases of the nervous system, where they have proved useful, presents features similar to those which occur in discontinuous conductors. It is not claimed by M. Branly that anything more than a mere analogy has been shown; but he thinks it possible that such considerations may prove a useful guide in determining the modality in which electricity is to be employed in a given case, and perhaps furnish the electro-therapeutist with a good working hypothesis.

"So far it is evident that such speculations fall very far short of this. All that can be claimed is to have made out a case for further inquiry. Such a line of investigation has already been foreshadowed in an article by me which was published in the 'Lancet,' May 4th,

1895, and in which the following sentence occurs:—'It seems even conceivable that other histological arrangements—*e. g.* those nerve-fibrils which conduct yet only touch and do not anastomose; those motor-nerve endings which are only in contact with the sarcous substance; indeed, any conducting arrangement in the animal body which may be classed as a "bad contact" may constitute the physiological analogue of what would be electrically known as "a coherer." ' "*

Neurasthenia.—The electrical treatment of that distinct clinical entity known as neurasthenia may be best described by such a case as the following; † inserted here because it is a typical and uncomplicated case, and such cases ought always to be cured:

CASE.—A physician, 46 years of age, of a neurotic family, strictly temperate habits, in active professional work, and living in an atmosphere of considerable social excitement, suddenly broke down about seven months ago. His first and greatest trouble was insomnia. Obliged to give up work, he underwent during three or four months a variety of medication, and was eventually sent to me by his medical man for the electrical treatment of the insomnia. I saw him for the first time early in February. He was not emaciated, pallid, nor bloodless. With most of the external appearances of good health, he was yet the picture of a neurasthenic—and, it may be added, the embodiment of self-concentration. His mind never for a moment strayed from himself and his ailments. In every line of his story and in every lineament of his face there was the history of nervous exhaustion—of too much work and too little rest, telling on a nervous system unstable by heredity. With minute exactness he details his symptoms and analyses his miseries. In case he should overlook anything he comes armed with a slip of paper, a few notes of his case—"l'homme aux petits papiers," as the French physicians call a figure not unfamiliar to the consulting-room. The first symptom on his list is sleeplessness. He cannot sleep. There is no pain or any great discomfort, or anything in his surroundings to account for it; he simply does not sleep. He has tried everything. He has denied himself his afternoon nap in order to secure his sleep at night—a great mistake, for in conditions like this, *sleep brings sleep*. He has darkened his room and closed his eyes; he has lighted his candle and read his book; he has tried count-

* "A Theory of Nervous Conduction," by W. S. Hedley, M.D., 'Lancet,' April 9th, 1898.

† See paper by the Author, 'Lancet.'

ing, repeating, saying his prayers; he has followed the ticking of the clock and thought of the humming of bees. Of course, following distinguished example, he has tried a glass of water on going to bed and an endless list of similar devices. He has tried a multitude of drugs, for some of which he has an intolerance by idiosyncrasy. Now he relies almost exclusively on sulphonal, which gives him sleep (generally on the following night), but which, he considers, is not without evil effects of its own. He spends his day in dread expectation of the coming sleepless night. Should he happen to sleep soon after lying down, he invariably wakes again in an hour or so. His sleeping is ushered in by sleep jerks, haunted by nightmare and dreadful dreams, and his wakening is accompanied by no feeling of being rested and refreshed. The insomnia, at first a consequence, is now a contributing factor to his mental and physical prostration. He has head symptoms; one of the earliest of these was vertigo. He chooses the side of the street with railings to the houses that he may be able to grasp them should his giddiness come on. Now he suffers from headache, not very severe, but like a band round his head, or a weight, or a heavy hat pressed down tightly (helmeted headache of the "galeati" of Charcot). It is a day headache, not a night one. There is hyperæsthesia of the scalp. Intellectual work has become difficult, almost impossible; he cannot even write a letter. Once a man of action, of courage and resource, he is now pusillanimous and hesitating, and leans on others. There is an obvious condition of cerebral depression, a decrease of will-power, a feebleness of character, a diminished power of resistance. He is emotional to an extreme degree, and "breaks down" on the most trifling occasions. Once, sitting at the play, interested and amused, and surrounded by laughing faces, a cloud suddenly seemed to come across his mind, everything looked black, his prospects seemed hopeless, he lost his self-control, and burst into tears. He suffers from dyspepsia, for the most part of the atonic flatulent kind—the stomach rises into the thorax. There is exaggerated resonance over the whole abdomen from inflation of the intestine, and this distension interfering with the descent of the diaphragm has its effect on respiration. He complains of muscular debility and a vague feeling of lassitude. The grasp of his hand or his squeeze of the dynamometer shows notably less force than would be expected from a man of his muscular development. He has already said enough to stamp him a neurasthenic. But, continuing the investigation of his case, a second line of symptoms comes into view. There is a peculiarity about his manner—an excitability, an impulsive restlessness. He shows a marked tendency to hypochondriasis, and, as already stated, is apt to take a

pessimistic view of the whole situation. He is evidently in the habit of going about from one medical man to another, never weary of talking of himself and his ailments; but (and here comes an important point in diagnosis with reference to a possibility which could not fail to suggest itself) he listens reasonably and thankfully to words of encouragement and advice. He leans on the opinion of his medical attendant. At times he exhibits peculiarities of gait that look almost like hysteria. He walks cautiously, with a stiffish spine and occasional peculiarities of movement, almost mimetic of some serious organic lesion. Besides the general weakness of his nervous and muscular system, he describes fibrillary tremors of the muscles and jerks of the limbs, as well as disorders of sensation, tingling of the feet and fingers. The knee-jerks and superficial reflexes are normal, as are the electrical reactions. There seem to be no pressure points or areas of exaggerated sensibility over the spine, but there is an evenly distributed increase of the general cutaneous sensibility. He is intensely sensitive to heat and cold and all atmospheric changes. The conjunctivæ are a little congested, the upper eyelids being slightly œdematous. The pupils are perhaps faintly unequal, but inequality is not constant. There is no retinal congestion. He is extremely sensitive to noise. There is constipation and a malodorous condition of the morning urine, which contains no albumen and no sugar. The tongue is furred. Palpitation is induced by the slightest excitement; a trifling movement or a meal may bring it on. The pulsation of the larger arteries is excessive and at times tumultuous. He watches with anxiety the throb of his carotids, and anxiously compares it with that of his nurse or friends.

Such is the case, and insomnia the symptom to be met. A hopeful prognosis may be given, inasmuch as in electrisation there exists an agent well adapted to meet both the symptom and the disease—a sedative tonic. Of course there is the usual initial difficulty; such patients are hypersensitive always, and shrink from a proceeding which they are sometimes accustomed to associate with "a shock." Therefore, by way of making a beginning, I passed the weakest perceptible faradic current through my own body, and with my hand administered for one or two minutes to his forearm the mildest of labile applications. He at first shrank back, but soon admitted that it was not disagreeable. I asked him to come again the next day. He did not come for a week, and then only at the renewed request of his medical adviser. He then explained that, though he was "no worse," and quite convinced that the electrisation was as mild as it could possibly be made, still the "exquisite sensitiveness of his organisation" was such that he had felt pricks and tinglings and "sensations" ever

since. He was then prevailed upon to step into a bath having a temperature of 92° F., and with his consent a continuous current of a few milliampères was passed through it—foot electrode, anode; cervico-lumbar, cathode. This was very gradually raised to 50 milliampères for five minutes. He slept well that night. Of course he said it was the warm bath. Possibly it was, but it was the thin end of the wedge. During the next week he had four or five such baths, with a gradually increasing current (up to 150 milliampères) and a gradually increasing duration (up to fifteen minutes), without, perhaps, any marked improvement in his insomnia, but with a perceptible rise in his general level of health. This treatment was continued until February 18th, and resulted in a less frequent necessity for resort to sulphonal, his average of sleep during the last week of this period having been from three to four hours. Direct head treatment was then entered on. Using the hair as a rheostat, a continuous current, cautiously raised to 2¾ milliampères, was passed from the forehead (anode) to the nape (cathode) for a minute, followed by subaural application (anode) of 5 milliampères stabile on each side for half a minute. This was followed by labile anodic galvanisation (5 milliampères) of the neck (cervical spine, back of ears, and anterior border of sterno-mastoid), the cathode being at the epigastrium. The whole proceeding lasted about five minutes. Between the first date of this application (Feb. 18th) and the end of the month a similar procedure was almost daily carried out, sometimes twice on his worst days. However prostrate and depressed on his arrival, he always on going away after such an application expressed himself as feeling better, brighter, and more equal to bodily or mental effort. This treatment, with slight modification, was continued, with the result that his average of sleep between Feb. 18th and Feb. 28th had risen to five hours, and he had not taken sulphonal since Feb. 18th, nor any other drug, excepting a very occasional dose of bromide of potassium, which he has taken ever since the beginning of his illness. Between Feb. 28th and March 24th this treatment, with occasional faradic baths, was steadily pursued, but with decreasing frequency and duration, and by that time (March 24th) his average of sleep for the twenty-four days having been six hours, the treatment was discontinued—that is to say, after seven weeks of treatment, consisting of about thirty sittings and twelve baths, sleep was practically restored. Not only this, but the general health and moral condition were strikingly improved. Instead of dark forebodings and pessimistic views he talked cheerfully and hopefully of going back to work again. On April 1st the improvement was not only maintained, but was still progressive.

The electrostatic bath was not used in this case, but is often in the highest degree useful.

Exophthalmic goitre.—Electrisation, general as well as local, ought never to be omitted in this disease. Want of success largely depends upon the very inadequate currents used. In the first place the current must be localised upon the antero-lateral part of the neck; the electrode hemicylindrical in form, and of large size (negative), must surround the entire thyroid body. Currents of 25, 30, and 40 ma. must be used. The indifferent electrode is placed in the usual position below the back part of the neck. In addition to this, faradisation of the orbicularis palpebrarum, of the cervical ganglion of the sympathetic and of the precordial region is proper. For the first an olive-shaped electrode may be used, and a current strong enough to produce contraction, one minute to each muscle. The cervical ganglion of the sympathetic is treated with the same current and the same electrode; the latter being placed at the angle of the lower jaw between the hyoid bone and the anterior border of the sterno-mastoid. The strength may be gauged by the action of the platysma producing a slight distortion of the face. Duration one minute on each side. For the treatment of the precordial region: an electrode 20 sq. cm., current strong enough to produce contraction of the pectoral muscles, duration three minutes. The treatment should be daily, and should last for two or three months. (Bordier, Vigouroux).

Cardew's method is definite but exacting. Apply anode to lower cervical spine, cathode to side of neck, labile from mastoid process to clavicle, 2 to 3 ma., six minutes, three times a day. This method is certainly less effective than that previously detailed, and necessitates the application of electricity by the patient, which is seldom permissible. Treatment to continue for three months. The hydro-electric bath and other methods of general electrisation are also useful.

Parkinson's disease (paralysis agitans).—No permanent

success seems ever to have attended the treatment of this disease by any method, electrical or otherwise. General electrisation sometimes temporarily diminishes the tremors. Hypnotism often produces a similar and better effect. But neither form of treatment is, in the opinion of the writer, equal to "colossal" doses of hyoscyamus.

Athetosis.—General electrisation may be tried.

*Paramyclonus multiplex.**—General electrisation by static charging. Assuming that there is a neurosis showing itself by an exaggerated irritability of the cord, or also by a peripheral neuro-muscular disturbance, stabile galvanisation of the cord and of the affected limbs is a rational treatment. Medium currents, say 8 to 10 ma., for fifteen to thirty minutes.

Chorea.—General electrisation by static machine, and hydro-electric baths. Many cases have got well under such treatment; but in view of the natural tendency of the disease to get well under any form of treatment, or without treatment, it is difficult to say that electricity is an effective remedy in chorea. It habitually fails in relapsing chorea; such improvement as may have followed the electrisation lasting only for a few hours.

Tetany.—Sedative treatment, such as anode stabile to the affected part, negative pole on spine.

Convulsive tics.—Any sedative form of treatment, such as stabile application of the anode, is indicated. Static charging should also be tried; but electrical, like other methods, have not met with any great success, although Erb and other trustworthy authorities give details of successful results. Perhaps the necessary time and patience are often wanting in the treatment of such cases.

Writer's cramp.—This condition, having its origin doubtless in an irritable weakness of the central nervous system, ought to be treated by general electrisation, central galvanisation,

* First described by Friedrich, 1882. A condition characterised by clonic convulsions or spasms of muscles of limbs, face, or trunk—usually symmetrical—and especially liable to appear on lying down in bed.

hydro-electric bath, or static electricity. In the latter the *séances* may be daily, lasting for a quarter of an hour, and continued not longer than a fortnight at a time. Local treatment to the affected muscles is also indicated. Negative pole to cervical spine, anode to muscles of hand, stabile 2 to 8 ma.; time, three or four minutes. In all cases of neuroses the occupation must, of course, be given up.

Migraine.—Assuming that contributory causes, such as stomachic or intestinal trouble, gouty or rheumatic conditions, errors of refraction, &c., have been dealt with, treatment will be directed to alleviation during the attack; and chiefly to an attempt to diminish the tendency to recurrence. Static charging is a most effective form of general electrisation; and treatment can at the same time be localised on the part by means of the "souffle." This is best carried out by placing the patient on the insulating stool, and directing the negative souffle upon the most painful point. Treatment daily ten to fifteen minutes. The stabile application of the galvanic anode (see first method of treating tic douloureux, p. 192) may also be tried during the attack. In dealing with migraine it is always to be remembered that it is a manifestation of a general condition.

CHAPTER IV

Electro-therapeutics of Rheumatism: of Gout: of Diseases chiefly characterised by Vaso-motor and Trophic Disturbances: of Diseases due to Failure or Perversion of Nutrition

Rheumatism and gout.

In chronic and subacute forms of joint trouble, whether rheumatic, rheumatoid, or gouty, and in muscular conditions having a similar origin, the usefulness of electrical treatment seems to lie (1) in the power of removing inflammatory products by the quickening of the circulation and dilatation of the blood-vessels that follow localised applications; (2) in the stimulant and alterative effect upon general nutrition of generalised electrical applications. These may take the form of galvanic, faradic or sinusoidal currents in the water bath, or static insulation, or sparks, or currents of great frequency and high potential. Localised applications may be of the following kind:—If much pain, galvanic anode with electrode enveloping the joint, 10 to 20 ma. eight to twelve minutes stabile; indifferent electrode at some distance. If the disease is very chronic, with thickening of structure and deposits of old standing, not accompanied by pain, the cathode must predominate, using currents of 15 to 30 ma. Localised faradism is often effectual in diminishing pain and improving circulation. The faradic brush can also be used in some painful conditions. Treatment is to be carried out on alternate days.* In chronic rheumatism and rheumatoid

* On the intervening day treatment may be usefully supplemented by the prolonged application of high temperatures (220° and upwards, forty to sixty

arthritis the hydro-electric bath is often the best expedient. Continuous, induction coil, and sinusoidal currents have all a good record; material improvement in the suppleness of the joints often follows their use, and an absence of the acute exacerbations so common in rheumatoid arthritis.

The introduction of lithium or iodide of potassium by cataphoresis finds a useful field here. In treating the conditions under consideration, and in any stage, no procedure is more useful than the following:—Place the affected joint in a 2 per cent. solution of chloride of lithium, immerse the + pole in this (using a carbon electrode); the negative or indifferent pole is attached to two large electrodes of 150 sq. cm. each placed upon the patient's back. Use 20 to 60 ma. for twenty to twenty-five minutes daily.

CASE.—M. B—. Had already had three attacks of acute articular rheumatism. On October 10th was seized with violent rheumatic pains in wrist and elbow; swelling of entire hand. Treatment by the lithiated bath commenced October 11th. Current 30 ma.; duration forty-five minutes. Hand and elbow placed in bath. After the third treatment could use hand. Swelling had disappeared on sixth day; elbow still a little painful. (Bordier.)

Lumbago.—The static spark is efficacious, and is recommended by the fact that it does not involve removal of clothing. This is carried out as follows (Renault):—The part ought to be submitted to static sparks for ten or fifteen minutes, the capacity of the machine being reduced as far as possible by taking away the condensers. An hour afterwards another application of sparks of ten minutes' duration; these often result in cure; but application to be repeated if necessary. When the patient cannot leave his bed give him at home one treatment with faradism, followed by a mustard plaster. He will be able to come for sparks the next day. The faradic brush also is often a rapid and

minutes); direct radiant heat from a luminous source being the most effective form of heat to employ. The electric light bath is the ideal sweat-bath.

effective remedy; and the same may be said of the continuous current. (See Myalgia.)

In the absence of any certain pathology for lumbago, it is permissible to suppose that, under the influence of atmospheric changes, some molecular modification in the muscle tissue occurs interfering with its regular nutrition; whence may result the products of insufficient metabolism which irritate nerve endings, causing pain. Or possibly, these hypothetical molecular derangements caused by cold or other agency, occur first in the nerves—a sort of neuritis—and this may be the cause of the deranged nutritive exchanges in the muscle.

Gout.—Static electricity is useful in the treatment of hereditary gout. Its timely application may ward off an attack. It probably stimulates the liver, intestines, and kidneys. It improves the circulation, promotes excretion, relieves the organism of its uric acid, and combats nervous exhaustion. Continuous current and sinusoidal baths are also recommended after an acute attack, as well as currents of great frequency and high potential.

The lithium bath, as recommended for rheumatism, is often useful during an attack of gout. The following is a case:

CASE.—B—. Rheumatic history. Typical attack of gout in big toe; pain, redness, swelling. Lithium bath, using current of 25 ma., twice a day. After fourth bath, improvement. After seventh application swelling and redness gone, and only a little uneasiness on pressure. (Porter and Jourdenet.)

Fibrous Anchylosis.—Soak large electrodes in solution of sodium chloride and place them on each side of joint, the negative nearest to the adhesions. Current 20 to 50 ma. for ten to thirty minutes, twice a week. Inflammatory symptoms must be absent before commencing treatment.

Chronic tendinous synovitis.—The following is the treatment, and a case (Bordier). Active electrode negative, 25

sq. cm.; current 20 ma.; duration 15 minutes. Indifferent electrode on back. Treatment daily.

CASE.—G—. Swelling of ankle from sprain a year ago; circumference at swelling 27 cm. Sound limb at same level 21 cm. Treatment commenced July 18th and ended August 2nd. Circumference of swelling 22 cm. This did not further diminish, but the patient could take long walks and was practically cured, and continued well when seen twelve months after.

Hydrarthrosis.—Treatment as above.

Myalgia.—Rheumatic muscular pains when situated in the back are called lumbago, in the neck torticollis, in the muscles of the chest pleurodynia. Speaking generally, myalgic pains are treated with the positive pole on the affected muscle. The active electrode should cover the painful part; current may be carried to 30 to 40 ma., with an electrode 100 sq. cm.; duration ten minutes; application daily, afterwards every second day. Such treatment seldom fails.

Torticollis.—It is usually the trapezius and sterno-mastoid that are the affected muscles. Galvanic or faradic currents may be used; the former after the manner just laid down for myalgia in general. Faradism in the form of "swelling" currents is used, *i. e.* the strength is increased until a very distinct contraction is obtained; then it is reduced by degrees to zero, and the procedure repeated fifteen to twenty times.

Diseases characterised by trophic and vaso-motor disturbance.

Zona (herpes zoster).—The eruption is acute and follows the direction and distribution of sensory nerves, is limited to one side of the body, and accompanied by neuralgic pains. Treatment of acute conditions not electrical, but electrisation is useful against the rebellious neuralgias that sometimes follow (see p. 192). General electrisation is also useful in preventing recurrence of attacks.

Hemiatrophy of face.—"A facial trophoneurosis." Occurs congenitally in infancy or at least before twenty-five. Is preceded by neuralgic pains in the region of distribution of the facial nerve, by spasms of the facial muscles, vertigo, heaviness of arm and hand of opposite side. Spots appear

along the direction of the filaments of the trifacial. The skin then becomes thin, indurated, and "cicatricial." The other structures of the face partake of the atrophy of the skin. Sometimes there is neuralgia. Sometimes the sensory troubles are limited to a feeling of formication. The disease is nearly always progressive. The trouble belongs to the nervous system. Electricity should always be patiently tried. Its success is very doubtful, but with any other form of treatment failure is certain.

Sclerodermia.—Continuous current in the form of general and local hydro-electric baths is useful. In certain forms of the disease try local electrolysis with a current of 5 to 10 ma., the needle being placed obliquely in the skin and not below it. More recently static electricity has been used in the form of small sparks, made to play always upon the same point of skin. This is carried out as in the treatment of eczema, small sparks being substituted for the breeze. Both general and local treatment is thus secured.

Raynaud's disease (local asphyxia).—Characterised by an arrest of capillary circulation attacking symmetrically the extremities, especially the fingers. (1) Place the affected extremities in bowls of water with an electrode in each; 5 to 10 ma. Duration ten to fifteen minutes. (2) Place anode over fifth cervical vertebra, cathode upon sacrum, large electrodes, 15 to 20 ma.; duration fifteen minutes. Take care that the skin of the hands does not vesicate.

Erythromelalgia.—An affection of the extremities, especially the lower. Characterised by pain, rose-coloured swelling of skin, elevation of local temperature. Use continuous current, local and spinal, as in Raynaud's disease.

Diseases due to failure or perversion of nutrition.

"*Arthritism*" (Bezin), "Herpetism" (Lancereaux), "Acid diathesis" (Bence Jones, 1867).—Currents of great frequency and high potential have shown a marked influence in improving the nutritive exchanges, increasing strength, and accelerating the diminished oxidations (see p. 68).

Diabetes.—Apostoli and Berlioz have stated that in three

diabetic patients submitted to the action of currents of great frequency and high potential the amount of sugar has much diminished; and in other cases where this result has not been secured the general condition of the patient has nevertheless been improved. The currents in question should certainly be tried in suitable cases of diabetes.

CHAPTER V

DISEASES OF THE ALIMENTARY CANAL. INCONTINENCE OF URINE. ASCITES. RICKETS. SUSPENDED ANIMATION. ELECTRICITY A TEST FOR DEATH

Paralysis of soft palate.—Induced or continuous current directly to the part by a curved electrode, the indifferent one being, as usual, below back of neck. Current strong enough to produce contraction of tongue muscles and lips. Diseases of the alimentary canal.

Anæsthesia of pharynx.—Induced or continuous currents, percutaneous or pharyngeal. Short static sparks often useful.

Vomiting.—Two electrodes, each 2 cm. in diameter, both attached to the positive pole, are placed one over each pneumogastric, between the two insertions of the sterno-mastoid. Indifferent electrode, 100 sq. cm., upon epigastric region, attached to negative pole. Current 5 to 10 ma. If nausea is threatened, the current must be at once run up to 15 to 20 ma. until the patient feels better; then the current is slowly reduced to 5 ma. Duration varies a good deal—perhaps, on an average, ten to twenty minutes. Two sittings a day sometimes necessary at commencement—eight sittings. Patient must rest afterwards, and should be near the doctor to have another application immediately a relapse is threatened. (Apostoli, Bordier.)

Dilatation of stomach.—Static induced currents (see p. 60). The patient (not insulated) is placed near one of the conductors of the machine. The external coating of one of the Leyden jars is put to earth, and the external covering of the other Leyden jar is attached to an ordinary exciter

terminated by a small ball. This is applied to the uncovered epigastric region. The distance of the poles of the machine is such as to give ten to fifteen sparks a second. Leave the exciter on one spot for a couple of minutes, then displace it to another (Bordier). Duration ten minutes. Eighteen or twenty sittings.

Nervous dyspepsia.—Place indifferent electrode, 300 sq. cm., over the lumbar region. The active electrode, 100 sq. cm. (negative pole), is applied to epigastric region. Current 30 to 40 ma. Duration ten minutes. In certain cases it is useful to rhythmically break and make the current to produce gastric movement.

Constipation.—There are three ways of treating constipation:

1. The patient is placed on the insulating stool and sparks taken from the iliac fossa for some minutes. This, in nervous persons, sometimes produces an evacuation.

2. Place on each iliac fossa an electrode 100 sq. cm., the negative pole on the left side. Use either a faradic or galvanic current, strong enough, by means of regular interruptions, to produce abdominal contractions. Duration ten to fifteen minutes.

3. Direct galvanisation of rectum by means of the rectal electrode. Through the electrode introduce 200 cub. cm. of a 5 per cent. solution of NaCl. The negative pole is used, the positive being a large abdominal electrode. Current 15 to 20 ma. Every two minutes the current is reversed. Duration eight minutes; three times a week.

Intestinal obstruction.—In the treatment of pseudo-strangulation, although faradisation has a good record, the continuous current shows its superiority in dealing with that condition of diminished excitability always present. Until the hydro-electric method was introduced, the difficulty of applying the continuous current lay in the necessity of avoiding escharotic effects at the active electrode. The electrode for insertion into the rectum must be capable of reaching as

far as the sigmoid flexure. This long, curved, insulated electrode is so arranged as to carry a stream of water from the irrigator, as well as a wire attached to one pole of a battery to convey the electric current. The water thus filling the bowel carries the electric current to the intestinal wall. The procedure is this :

A suitable quantity (one to three quarts) of salt water having been placed in the irrigator, the abdominal pad having been adjusted and attached by a connecting wire to the battery, and the active electrode having been introduced, the latter is connected up to the positive pole of the battery by a wire, and to the irrigator by a tube; the cock of the irrigator is then a little opened and half its contents are allowed to pass slowly into the intestine. The strength of the electrical current will depend on the state of the patient and the probable cause of the obstruction. The intensity may be 10 to 20 ma. or even more. The length of time during which the current is allowed to flow will be from five minutes to twenty minutes. In many cases, such as pseudo-strangulation and fæcal obstruction, it is sufficient to use the continuous current without reversal or interruptions, but "when there is an obstacle to overcome it is necessary to add stronger excitation." In the latter case after the current has passed for five or six minutes it should be reversed by first bringing the needle to zero and again raising the current to its former intensity. By this "an intestinal contraction is almost always produced." When the patient can no longer control the action of the bowels the operation must be suspended, and he must make efforts at defæcation. Then one of three things will follow : either an abundant evacuation will take place, or there will be only some liquid matter and gas, or the injection will come away hardly coloured. In the last two cases another application must be made, but not until seven or eight hours have elapsed. Having made three applications in twenty-four hours without success, further attempts by this method

must be discontinued. Such is the procedure as laid down by Larat, and it is here detailed very much in his own words. He, of course, adds that in unsurmountable obstacles, such as ileus or twists of the intestine by adhesion, the only remedy is operation; but that in the case of a foreign body in the intestine or of a tumour where the obstruction is not absolute, in paresis of the intestine, pseudo-strangulation, constipation, and fæcal obstruction, the procedure in question is likely to prove successful. But, in point of fact, on being called to a case of obstruction of the bowels with the abdomen distended and tender, some collapse and a feeble pulse, an accurate diagnosis of the cause of the obstruction is usually almost impossible. Therefore in all such cases, after a purgative and enemata have failed, and before resorting to any surgical operation, the electric injection ought to be used, and used with all possible care, in view of the fact that failure involves an operation whose mortality, even with every antiseptic precaution, is but little under 60 per cent.*

Hæmorrhoids.—Both the external and internal variety may be dealt with as follows:—Having exposed the hæmorrhoid, apply by means of the rectal speculum a carbon or platinum electrode with cocaine solution on absorbent material (see Cataphoresis) with a current of from 15 to 25 ma. for seven minutes (if general anæsthetic has not been used). Then taking a small platinum needle attached to staff six inches long and insulated to half an inch from the point, insert it in the hæmorrhoid and gradually turn on current of 5 to 20 ma. for ten minutes. Blanching occurs, and the operation may, perhaps, be carried out, and the needle withdrawn without bleeding. Deal similarly with other hæmorrhoidal tumours. "If the needle has been insulated in such a way that one eighth of an inch of shellac in solution will follow the point into the hæmorrhoid, further inser-

* See 'Hydro-electric Methods in Medicine,' W. S. Hedley, M.D. (Lewis, London.)

tion being guarded against by a shoulder or bulbous portion, the after-treatment is very slight," consisting of cleansing injections of acetanilid after defæcation, and occasional applications of a similar ointment. (Massey.)

Prolapse of rectum.—CASE.—Bridget G—, aged 50, married. Prolapse of rectum; tissues indurated and thickened. A felt-covered, flat electrode placed under sacrum; patient on back. Ordinary rectal electrode inserted into rectum, connected with positive pole. Rapid vibrator. As soon as the current was regulated to agreeable strength, slow interruptions were made by touching one of the terminal posts with the tip of the conducting cord. This produced a good form of muscle contraction; better than the action of the vibrator. Duration ten minutes. No prolapse after first treatment. (Massey.)

Notwithstanding the above case, it will usually be found that the continuous current is the more effective. Cathode at anus in the shape of an olive-shaped electrode, covered; anode at lumbar region. Current must be at first mild and gradually raised, even to 20 ma. Treatment every other day for five minutes. Before commencing replace the prolapsed bowel.

Fissure of anus.—Before resorting to any surgical proceeding the following method ought to be tried. The negative (indifferent) electrode is placed on the abdomen, while the positive platinum electrode covered with absorbent cotton, saturated with a 10 per cent. solution of cocaine hydrochlorate (Massey), is applied to the fissure, using a current of 1 to 5 ma. for several minutes. Repeat, if after a sufficient time healing has not occurred.

Incontinence of urine from atony of sphincters.—Increase muscular tone by faradisation applied by simple urethral bulbous electrode, the indifferent electrode being immediately above pubis. Use "swelling" currents, *i. e.* rather strong currents kept gradually increasing and diminishing in amount, six to eight minutes. This may be repeated almost every day. Treatment of the cord may also be carried out with a view of influencing the vesical centre, and any injured point higher up that may cut it off from cerebral influence. Incontinence of urine.

Nocturnal incontinence in children.—One pole on perinæum, the other over symphysis. Coil currents with slow interruptions for ten minutes every day; or, in an obstinate case, treatment may be more effectively given by applying the small urethral electrode to the sphincter instead of the pad to the perinæum.

Ascites.

Ascites.—It is unnecessary to say that treatment and its results must be gauged by the cause of the condition in each individual case; but, speaking in a general way, it may be stated that a vigorous faradisation of the abdominal muscles, kept up for ten or fifteen minutes, has been credited with producing an increase of kidney activity and decrease in the ascitic fluid. The writer has notes of cases improved by the use of sinusoidal current water baths. Electrical treatment of this kind will usually go hand in hand with other treatment and with the use of the dry radiant heat bath, the head being excluded.

Rickets.

Rickets.—General electrisation by the hydro-electric bath is the best form of treatment. Static charging, central galvanisation, or general faradisation are also useful according to the special features of the case.

Anæmia and chlorosis.

Anæmia and chlorosis.—Hydro-electric bath, using sinusoidal or induction coil current on general principles.

Suspended animation.

Suspended animation.—Attach two olive-shaped testing electrodes to the induction coil; place them upon the motor point of the vagus on each side by pushing them under the outer edge of lower part of the sterno-mastoid, or between the insertions of that muscle; open and close the circuit about thirty times a minute with the key in the handle of one of the electrodes. Each closure produces an inspiration. Electrical stimulation about the face and upper lip also tend to excite respiration. General stimulation of the surface of the skin by the faradic brush produces useful reflex effects in cases of narcotic poisoning.

Electricity a test for death.

Electricity a test for death.—Forty years ago this subject was investigated by Crimotel, twenty years later by Rosenthal,

and more recently by Onimus. It is safe to say that in no disease—certainly in none of those conditions usually enumerated as likely to be mistaken for death—is galvanic and faradic excitability absolutely lost in every muscle of the body. On the other hand, electro-muscular excitability disappears in all the muscles within a few hours after death, generally in ninety minutes to three hours (according to Rosenthal), its persistence varying to some extent with the particular muscle examined and with the mode of death. Contractility to electrical stimulation disappears more rapidly in death from chronic than from acute disease, more rapidly in wasted than in well-nourished muscles. Experimenting on a guillotined criminal, Onimus found that two and a half hours after death electro-muscular contractility disappeared in the tongue, diaphragm, and muscles of the face. In the limbs the extensors died before the flexors. The muscles of the back were contractile up to five or six hours after death; the abdominal muscles longer still.

Therefore if electro-muscular contractility be present in any muscle, it can only mean one of two things: either that life is not extinct, or that death has occurred only a few hours before.

It is clear that no interment or post-mortem ought to take place so long as there is any flicker of electro-muscular excitability. It seems almost equally obvious that in all doubtful cases, sometimes in sudden death, and often to allay the anxiety of friends, this test ought to be applied, and applied by one who is accustomed to handle electric currents for purposes of diagnosis.*

* Communication by the author, 'Lancet,' October, 1895.

CHAPTER VI

Diseases of Organs of Special Sense. Aneurism

The eye.

Paralysis of ocular muscles.—See General Methods.

Opacities of cornea.—The principle of treatment is to induce stimulation sufficient to bring about gradual absorption, but stopping short of any irritation sufficient to cause inflammation. After applying cocaine, the patient, seated with the head thrown back, is directed to press the anode against the cheek of the affected side. With the thumb and first finger of the left hand the operator separates the lids to prevent contact with the electrode. He then gently places the latter upon the cornea, using a current of ½ to 1 ma. for one minute. This is subsequently increased to 2 ma. according to the toleration of the patient. The finger of the operator is perhaps the best electrode. If of metal, the electrode may be 5 mm. in diameter. Special electrodes are constructed for the purpose. Treatment may be every second day. Cloudy opacities may disappear after half a dozen applications. Leucoma does not yield to this treatment. Do not persevere after fifteen applications without an interval of two months.

Trichiasis.—See Epilation.

Optic neuritis and atrophy.—When neuritis predominates, place anode on closed eye, cathode on neck, stabile. If no neuritis, transverse currents through the head may be used, but in the most guarded way; 2 ma. should not be exceeded. The treatment cannot be seriously recommended as a very hopeful one, especially in tabetic atrophy.

Stricture of canaliculus and duct.—See Strictures.

Granular conjunctivitis.—A needle is attached to the negative pole and its point applied successively to each granulation (Malgat). A better method is "metallic electrolysis" or "electro-medicamental diffusion" (see Cataphoresis). This consists in applying a copper electrode (attached to the positive pole) to the granulations, the negative ("indifferent" electrode) being below the back of the neck. An oxychloride of copper is formed, which is diffused over and into the tissues.

CASE.—P—, aged 21. Has suffered for a year past from photophobia, suffusion, and smarting of the eyes. Has ulceration of cornea and conjunctiva covered with granulations. Treatment: cataphoresis, copper electrode 3 ma.

July 24th.—Much better; no pain; less photophobia, &c. Treatment with the copper electrode 10 ma., two to three minutes.

July 26th.—Œdema of eyelids quite gone; cornea clear. Repeat treatment.

July 31st.—After fourth treatment nearly well.

Two further treatments given, and nothing more than a slight redness of conjunctiva. (Walk Morton.)

Metallic foreign bodies in the eye.—An electro-magnet is made with several detachable points for the removal of small pieces of iron and steel lying loose in the interior of the eye. Selecting a suitable point, it is screwed on and introduced through a small incision, and the particle if not firmly embedded in the tissues may be withdrawn. A few cells of any kind are sufficient to excite the electro-magnet, and this should be done by closing the circuit after the magnet is in position.

Nose and throat.

Ozæna.—Adopting the view that ozæna is caused by a special micro-organism (*bacillus mucosa ozænæ*), and putting aside other causes of fœtid discharge, such as necrosed bone, &c., and in view of the proved microbicidal action of oxychloride of copper, it is reasonable to expect good results from cupric electrolysis. At a meeting of Belgian

laryngologists and otologists in 1895, Cheval announced the cure at a single sitting of 91 per cent. of the cases of ozæna treated in this way. There is required for the operation: (1) a good constant current supply; (2) a reliable milliampèremeter; (3) a rheostat, or a cell-collector taking up one cell at a time; (4) partially insulated needles. The copper needle (positive) is pushed into the mucous membrane of the middle turbinated bone and a steel needle into the mucous membrane of the inferior turbinated bone of the same side. If the monopolar method be adopted, the positive, *i. e.* the copper needle, is used in the same way as above, but the negative or indifferent pole is represented by a large flat electrode placed upon the arm, the sternum, or the neck. Current employed, 18 to 20 ma. for ten minutes, up to 30 ma. for fifteen minutes, according to the gravity of the case. The circulation of warm air through the nostril has been added to the above method in the treatment of ozæna with encouraging results.

Rhinitis.—The relaxation and tumefaction of the mucous membrane often causes it to become hyperæsthetic, and a condition of acute coryza may sometimes follow on slight exciting causes. Treatment: the flat side of a cautery knife at cherry heat, over the redundant portion of the membrane covering the inferior turbinated bones, will effectually deal with this condition (Sajous). Cocaine anæsthetisation (4 per cent. solution) must be previously employed. Chronic and hypertrophic rhinitis, when uncomplicated, may be similarly dealt with.

Post-nasal catarrh.—After being cocainised with ether spray, a bulbous copper electrode attached to the positive pole is passed through the mouth to the affected part, the indifferent electrode being at the nape of the neck; current 5 to 8 ma. The metal is oxidised, and chlorine (evolved from the decomposition of the tissues) forms, with the copper, a secondary salt, the oxychloride of copper, which is diffused into and over the affected part. Here, as in the foregoing

cases, there is electrolysis of the metal, and cataphoretic transfer of the newly-formed substance into the tissues.

Paralysis of the larynx.—The treatment may be percutaneous or laryngeal. For the first a double electrode is used, placed over the larynx and attached to one pole; the other electrode is put in the usual position below the back of the neck. For internal applications it is necessary to be accustomed to the use of the laryngoscope. The induced current is used. In very recent cases galvanic currents percutaneously applied are often useful, one electrode being over the larynx, the other at the back of the neck. It is a matter of experience that the singing voice can be improved by the latter method.

Nervous aphonia.—Static sparks are usually effective. Ten or twelve sittings may be necessary. Faradic brush to the nape of neck sometimes effective.

The ear.

Tinnitus.—Select two small, well-padded electrodes, each 2 cm. in diameter, to form a divided anode; apply one to each ear just in front of tragus. The cathode is a large electrode applied to back of neck. The current is slowly raised to 5 ma. Duration ten minutes. A current of even 8 ma. may sometimes be used, *i. e.* four to each ear as the anode is divided. The anode usually diminishes the tinnitus, and the cathode increases it. Sometimes the reverse occurs. If no improvement follow either method of application, after one or two sittings, it is useless to persevere.

Eustachian obstruction.—See Strictures.

Aneurism

The scanty literature of the treatment of aneurism by electro-puncture goes back to Pravaz (1838), Peterkin (1845), Ciniselli (1870); and more recently Tripier deals with the subject, as do a few scattered articles in the weekly medical papers.* Ciniselli has collected twenty-three cases, six of

* 'Brit. Med. Journ.,' 1890, vol. i, p. 1276.

which recovered. He seems to have operated sometimes with one needle in the sac, sometimes with both. Tripier advocates the insertion of the positive needle only, on account of its property of coagulating albumen. It seems difficult to know how far the coagulating action of the needle introduced into an aneurism may be mechanical and how far the coagulation is electrolytic (chemical). In Ciniselli's cases it is not easy to arrive at the intensities employed. In some cases twenty to forty cells seem to have been used from ten to thirty minutes.

Dr. Stewart* reports good results by continuous current through gold wire introduced into the sac. The method is as follows: A fine coiled wire (gold, silver, or platinum) is used, previously so drawn that it may be readily passed through a thoroughly insulated needle of somewhat larger calibre than the wire. The amount of wire requires judgment. Dr. Stewart's figures for a globular sac are as follows: Sac 3 inches in diameter, wire 3 to 5 feet; for a sac 5 inches in diameter, 8 to 10 feet. Anode should always be the active electrode, the negative being a clay pad upon the abdomen. The current may reach 80 ma., using, perhaps, 20 to 50 during the first ten minutes, 70 in twenty minutes, and 80 in thirty minutes. Duration half an hour to one hour and a quarter. About a dozen cases are given; one is the following:

CASE.—Aneurism at junction of transverse and descending portion of aorta. Nine feet of gold wire used. Current quickly run up to 70 ma. Duration one hour. At end of forty-eight hours bruit gone and pulsation lessened. At the end of a month pulsation had disappeared. The patient shortly afterwards left the hospital in good health.

The present writer has no personal experience of this or of any other electrical method of treating aneurism.

* 'Philadelphia Med. Journ.'

CHAPTER VII

Diseases of Women

This chapter follows with intentional closeness the descriptions of W. W. Massey, of Philadelphia, and his book, 'Conservative Gynæcology,' cannot be too strongly recommended to those who wish to study the electro-therapeutics of this subject.

1. Uterine fibromas and myomas.

Clinical varieties.—A fibroid tumour grows from one or more matrices within the tissue of the uterine wall, pressing the normal uterine stroma before it, and tends to develop most in the direction of least resistance. If this centre of growth appears about the middle of the uterine wall, an equable enlargement of that portion of the uterus results, the unaffected tissues being displaced in all directions, giving rise to the most common clinical variety, known as the intramural tumour. If the centre of growth be nearer the mucous membrane than the peritoneal covering, it will in time project more or less into the uterine cavity, forming the submucous variety; and this may still further project into the cavity and, becoming pedunculated, form a fibroid "polyp." If, on the other hand, the centre of growth be nearer the peritoneal surface, it will again follow the lines of least resistance, and by projecting into the peritoneal cavity become subperitoneal, or, by a complete emergence, become pedunculated. (Massey.)

The object of treatment is to produce a symptomatic cure, *i. e.* relief of pain and hæmorrhage, as well as to relieve pressure symptoms and induce shrinkage of the tumour throughout. There is some misapprehension about the effects to be expected. The operator will be wise to aim, not at

producing a physical electro-chemical decomposition of the tumour—this would be followed by the undesirable formation of a sloughing mass—but by the use of milder currents to bring about a general shrinkage of the tumour. In the latter case the changes are of a trophic nature; currents of sufficient volume traversing the tumour cause "an inhibition of proliferating power of the abnormal cells," followed by quickened tissue waste and absorption through the lymphatics and veins. There is at the same time a trophic stimulation of the healthy surrounding tissues (Massey). If the direct action of the positive pole be desired, as, for instance, in dealing with a "hæmorrhagic tendency," a platinum or carbon electrode must be used. For this intra-uterine electrode Apostoli uses a sound covered with a sheath of hard rubber, this sheath insulating the metal to the extent desired; or a sound-shaped platinum electrode insulated with shellac may be used, the bare two inches at the end being of platinum. It is best to protect the os and cervix by carrying the insulation to such a point that will prevent metallic contact with these parts when the instrument is inserted. The indifferent electrode is an ordinary very large pad on the abdomen; or if very strong currents are to be employed, a freshly made clay pad. This is made of potter's clay, kept of the consistence of soft mud by mixing it with water in a covered vessel. It is most comfortable if heated, and this may be conveniently done by stretching a piece of tarlatan over the vessel in which the clay is heated, to enable the latter to be lifted out. The clay should be spread one inch in thickness, and large enough to cover the abdomen. A plate of lead or block tin almost as large as the pad, with an attachment on it for the conducting cord, should then be pressed down on the clay.

Operation.—(1) Dorsal position in a gynæcological chair, or lying across a bed with feet on chairs. (2) Antiseptic flushing of the vagina is insisted on by some. It is of far greater importance to have the hands and instruments aseptic. (3)

Place indifferent electrode attached to the desired pole on abdomen, having removed sufficient clothing to prevent wetting. (4) Any abrasion on abdominal surface must be covered with adhesive plaster or collodion, or paper smeared with vaseline. (5) Examine the insulation of the active electrode. (6) Examine cell collector or rheostat to see that the current is at zero. (7) Insert active electrode. (8) Intensity to be according to the indications. Slight cases of chronic endometritis unaccompanied by hyperplasia may be effectually treated by 20 to 30 ma. negative for five minutes. If there be hæmorrhage use positive pole. When there is a large intra-mural tumour, currents of 50 to 200 ma. are used. But currents of 30 to 50 ma. frequently repeated are often effective. Large currents (above 30 ma.) must only be used after having begun with lower ones to test the tolerance of the patient. Diminish current or stop application if pain is severe. A certain strength of current is doubtless necessary. A weak current over a long time is not equal to a strong current over a short time, although the electrolytic effect be the same. Further, even if the polar effect also be the same in the two cases, the interpolar tissue is by no means equally influenced. (9) Average duration of application, five minutes (Apostoli). (10) The current must be taken off very gradually. (11) Warn patient that she may have "colicky" pains for a day or two after the application, followed by some soreness. (12) She must rest during the remainder of the day after getting home. (13) If pain is severe the next day, or febrile condition established, it is a warning that there may exist some contra-indication to electrical treatment. (14) It is scarcely necessary to add that the intra-uterine electrode should never be inserted until careful investigation has been made as to the existence of pregnancy. Cases have been known where patients seem to have been deliberately reticent on this point. Neither should intra-uterine electrode be inserted during an acute inflammation of uterus or its appendages, nor any purulent lesion in pelvis, nor where ascites

is present (see Diagnosis, p. 132). Fibro-cystic tumours or very soft myomas are not suitable cases. (15) Repetition of the operation will depend on the kind of fibroid and the intensity of current; but if well supported the operation may be repeated every third day, and twenty or thirty repetitions may be necessary.

2. Menstrual derangements.

Amenorrhœa.—Arrange the application of the current so that the abdominal and pelvic sympathetic plexus and lumbar enlargement of the cord lie in its path. This can be effected by the patient lying on a large electrode, and applying a circular one with handle alternately to epigastrium and hypogastrium, stabile, using 30 ma. This should be followed by a strong primary faradic current. In some cases the intra-uterine electrode negative may be applied. It is scarcely necessary to say that sedentary habits, deficient assimilation of food, and auto-intoxication from accumulating secretions in the alimentary canal must have been in the first instance attended to.

Scanty menstruation.—Indifferent electrode on the abdomen; bipolar faradic currents from secondary wire to uterus or vagina; or galvanic currents (10 to 20 ma. negative) in same situation.

Dysmenorrhœa, or menstrual flow pain.—Menorrhalgia, restricting the term to painful menstruation of uterine type, excluding ovarian and inflammatory pain. Discarding mechanical theories, and regarding this as a neuro-muscular phenomenon, "a neuro-myotic storm of uterine nervous and muscular apparatus," abdomino-dorsal or spinal applications of 10 to 50 ma. are indicated. Current to be very gradually put on and taken off.

Uterine dysmenorrhœa.—Local treatment advisable, especially if endometritis present. One pole continuous current, negative, intra-uterine when increased flow desired; positive pole if endometritis; 15 to 50 ma. may be required, and two to six applications.

Menorrhagia.—Treatment: intra-uterine applications, 20 ma., positive; followed by faradisation.

Metrorrhagia.—Treatment: bulbous electrode, having active surface of 2 cm. long, and of suitable size, attached to the positive pole, carried to fundus, and current of 20 to 30 ma., for three or four minutes. Current then turned off and instrument withdrawn to the extent of 2 cm., when the current is again turned on for three minutes. This turning off of the current and partial withdrawals are repeated until bulb of electrode reaches internal os. Cervical cavity not usually treated.

Bare platinum electrode introduced into cervical canal; 5 ma. twice a week. Perhaps six weeks' treatment. **3. Cervical endometritis and erosion.**

Chronic metritis.—Galvanic anode intra-uterine, mild current, say 20 ma., followed by faradism. **4. Chronic metritis.**

Metrosalpingitis.—Vaginal application, galvanic and faradic. If intra-uterine application 20 ma. twice a week, with vagino-abdominal application at intervals. **5. Metro-salpingitis.**

Chronic ovaritis.—To ascertain whether an ovarian trouble is suitable for electrical treatment or surgical operation the following test may be of service. If a localised bipolar faradic application relieves pain more or less quickly, probably a neuralgic or congested condition scarcely inflammatory is present, and electrical treatment indicated. If intra-uterine application of 30 ma. to 50 ma. or less, made with a covered electrode, aggravates pain in a very decided way, probably a grave inflammation of appendages is present and operation necessary (see Diagnosis). **6. Chronic ovaritis.**

Vomiting of pregnancy.—Induction coil fine wire, anode at back of neck, cathode at epigastrium, avoid uterine region (see Diseases of Alimentary Canal). **7. Vomiting of pregnancy.**

Slow labour may be hastened, atony of uterus corrected, post-partum hæmorrhage controlled, inertia of uterus during labour overcome by use of faradic currents. Apply electrodes about the size of the palm of the hand on either side of the fundus near the umbilicus, and turn on a **8. Slow labour.**

vigorous coil current at the beginning of each pain, or when a pain is due.

9. Post-partum hæmorrhage.

Post-partum hæmorrhage.—Use the current of the primary wire with an intra-uterine electrode, the indifferent electrode being on the abdomen. Or the bipolar intra-uterine electrode may be used. Several forms of pocket faradic batteries are available for such purposes, notably those of Gaiffe, of Paris. The general practitioner will find this a great addition to his other resources in such emergencies.

10. Sub-involution.

Sub-involution.—Intra-uterine faradic applications are permissible in early cases.

11. Caruncle.

Caruncle.—This small tumour, situated at orifice of the urethra, can be treated in two ways. (1) If pedunculated the galvano-cautery snare is passed round it and current turned on, having previously been cocainised in the usual way,—that is, by using the carbon or platinum electrode covered with absorbent material saturated in the solution ; 5 to 15 ma. for some minutes. (2) If there be no pedicle, puncture with negative needle is the method employed, using 10 to 15 ma., until the appearance of the tumour denotes its impaired vitality.

CHAPTER VIII

Cutaneous Diseases

Eczema.—The treatment of eczema is a triumph of electro-therapeutics. It consists simply in placing the patient on an insulating platform, attached usually to the negative pole, and directing towards the eczematous patches the souffle or breeze from a point attached to the positive pole (see p. 62). The larger the output of the machine the better the result. Treatment ought to be every second day, duration ten minutes. Cutaneous disease.

Case.—B—, a woman aged 29, suffered from eczema, chiefly situated in the neck, and which had resisted all forms of treatment for nine years. There was thickening and induration of the skin and intense itching. Electrostatic treatment was commenced September 14th, 1895; daily sittings. Sometimes the bath was positive and the breeze negative; sometimes the reverse. Improvement first showed itself by a diminution in the itching. From the 15th October the negative bath and the positive breeze were used, with sittings every second day, and improvement became more marked. On November 2nd all the patches and itching had almost entirely disappeared. On November 16th was considered cured, and when seen three weeks afterwards was well. (Bordier.)

The hydro-electric bath in the hands of Gautier and Larat, and high frequency currents have also proved useful. With the latter Dr. Oudin has published some results. In applying the breeze from high frequency apparatus, a kind of small brush of fine wires is used attached to the high frequency coil, the other pole of the primary coil going to earth. The patient is not insulated. In acute cases the brush is held sufficiently distant from the skin to secure only the "breeze" effect. In more chronic cases sparks of 1 to

2 cm. in length may be allowed to play upon the part. (Oudin.)

Lupus of the face.—Electrolysis is convenient and effective. Two platinum needles attached to the positive and negative pole by a battery are placed in different lupus centres; current 5 to 15 ma. At the end of ten to thirty seconds the needles are removed, and so at one sitting a considerable surface can be treated. This ought to be repeated every three or four days, and the number of sittings may be twenty. Static and high frequency breeze useful.

Sycosis.—The following is the method employed by M. Boisseau du Rocher: Ten to fifteen silver needles attached to the positive pole are inserted into different points; indifferent electrode is below the back of the neck; current 3 to 4 ma.; duration ten minutes every second day. By this means oxychloride of silver is formed, which is diffused into the tissues by the current. (Metallic electrolysis, see p. 247.) It may take three or four weeks and twenty to thirty sittings to complete the cure.

Pruritus.—The electric breeze (see p. 62) is the remedy *par excellence* for this condition. The patient is seated on the insulated stool attached to one pole of the machine and a metallic point in connection with the other pole is moved slowly over the affected region at a distance of from 10 to 15 cm. Duration ten to fifteen minutes or more.

Anæsthesia.—1. For exploration of cutaneous sensibility see p. 125. The condition is due to an interruption in conduction of the sensory nervous filaments, or weakening of the terminal sensory mechanism central or peripheral. The objects in view are first to deal with the general condition that induces the loss of conduction, to augment the excitability of the sensory receptive organs, to overcome resistance to the transmission of sensory impulses, to deal with any troubles of nutrition that lead to functional derangements in the sensory apparatus. (Bordier. See also "A Theory of Nervous Conduction," p. 196.)

By far the most effective remedy for anæsthesia is the faradic brush, or the hydro-electric douche.

Epilation.—Until the power of the X-ray to destroy the papilla of the hair follicle is more completely established, electrolysis remains the best and only certain means of doing this. Method:—A fine needle, preferably with a minute bulbous enlargement at the end, is attached to the negative pole of a constant current battery, while the patient holds in the hand a well-wetted sponge-electrode attached to the positive pole. About six to seven cells (3 or 4 ma.) are used, or a greater number if not recently charged. The negative needle is then introduced as closely as possible to the root of the hair and pushed down the sheath, following the hair to the root of the follicle, but without piercing the latter. Then the patient is directed to squeeze the sponge and the current is completed, as shown by a little bubbling of gas where the needle enters. This is allowed to continue for five or ten seconds, when the patient is directed to loose his hold of the sponge, or the current is broken at the interrupting handle, and the needle is withdrawn. The hair may then be easily removed by flat-pointed epilation forceps; if it does not come away without plucking it, it is better left alone for treatment on a future occasion. Sterilisation of the needle before insertion by heating to redness is a proper precaution. A number of hairs lying very close together should be attacked on different occasions to prevent undue scarring. A large growth of fine downy hairs on the upper lip of a woman is not, as a rule, suitable for treatment by electrolysis.

"Cosmetic electrolysis."

Trichiasis.—Troublesome eyelashes can be removed by the above method, using cocaine freely if necessary.

Nævus.—When treatment by the knife is practicable electrolysis should not be used. The sooner after birth that electrical treatment is carried out the better. The needles may be alternately positive and negative, or all attached to one pole, and an ordinary pad electrode used for the other

Vascular nævi.

pole. Current varies up to 30 milliampères. Duration of electrolysis, six to seven minutes. Current must be gradually lowered to zero before withdrawing needles. Chloroform.

Port wine mark.—In this form of vascular nævus the object aimed at is to secure occlusion of the capillaries, and a series of small white cicatrices instead of the disfiguring colour of the nævus. In this case the active (negative) electrode consists of a number of needle points attached to a disc, so that many punctures may be made simultaneously; or only a single needle may be used. The current is cautiously turned on and carefully regulated, 2 to 3 ma. to each needle. Operations repeated at three weeks interval. Operation painful, and the use of anæsthetics presents the advantage of making it possible to prolong the duration of the *séance,* and so render a smaller number of applications necessary. The needles should be insulated excepting at the point, and according to the thickness of the nævus.

In all nævi the pole selected will vary with the vascularity, extent, and prominence of the nævus. The positive pole would be used in nævi containing large sanguineous cavities, or bleeding and erectile. For flat spots some of the needles may be negative and some positive; 30 ma. may be used, and an operation of a quarter of an hour will be sufficient to deal with an area of 140 cm. The needles are left long enough in one place (a little over half a minute) to produce a small subcutaneous eschar; they are then shifted a little, and the whole surface is dealt with by a series of such eschars very near each other.

Redness of the nose.—The bluish-red colour that is especially noticeable on coming from the cold into a warm room is sometimes a most annoying condition. Both poles of the battery are used on the part, labile. The strength of current will vary according to circumstances, but it should not be increased to the full toleration of the patient. A considerable number of applications are necessary.

Moles and warts.—Place the indifferent electrode positive

in the neighbourhood of the wart. A needle of steel or other metal is attached to the negative pole and, according to the size and shape of the growth, is inserted across its middle or just above its base, parallel to the surface of the skin, and the current brought to 4 or 5 milliampères. The current is allowed to flow till the colour of the wart changes, *i. e.* until tissue disintegration takes place, and the wart looks like a vesicle of herpes. When this has occurred the current is brought to zero. Time required generally two or three minutes for each wart. In a week to a fortnight the wart disappears, leaving no cicatrix. A local anæsthetic may be used in the shape of chloride of ethyl or cocaine cataphoresis. Another method is to attach both poles to sharp needles, and transfix the growth by the needles inserted parallel to the skin.

CHAPTER IX

Strictures—The Cystoscope—The Urethroscope—The Laryngoscope—The Vaginal Speculum

Strictures.

In the treatment of stricture it is the dilating and softening effect of the negative pole that is sought.

Stricture of urethra.—Having ascertained position of stricture in the usual way, (1) place the patient in dorsal position; (2) large indifferent electrode attached to positive pole is placed on abdomen or back; (3) use whalebone bougie with an olive-shaped head of suitable size; (4) let current be increased very slowly until slight pricking sensation is felt by patient. The current will be 3, 4, or 5 milliampères; in the female urethra rather more. Keeping the instrument in touch with the stricture, it will be found that the former slowly advances and passes through. When this is felt to occur the current is slowly turned off, and then, and not until then, the bougie is withdrawn. The operation may take only five minutes. In one or two weeks repeat the operation with a larger bougie. Weak currents, considerable intervals, and no force are the rules. If it is found after fifteen minutes or so that the instrument does not pass, the attempt had better be discontinued and deferred for a week. Pain should never occur in this form of electrolysis. In inflammatory conditions electrolysis is not suitable. For ordinary stricture the size of the bougie should be slightly larger than the stricture.

The requirements for the operation are the usual battery, conducting cords, milliampèremeter, cell collector or rheostat, and bougies à boule, assorted case. Dr. Robert Newman, of

New York, has been chiefly instrumental in bringing this method forward, and has had excellent results.

Stricture of rectum.—Treatment similar to urethral stricture, excepting that rectal electrodes are used with metal ends, flat or ovoid, sizes varying from a quarter of an inch to one inch in length, and one inch to three inches in circumference. Indifferent electrode is often most conveniently placed in the patient's hand. Currents may be 5 to 15 ma. Should there be evidence of malignancy, zinc electrode amalgamated with mercury may be useful, positive pole being employed.

Eustachian obstruction.—A large flat electrode positive is applied to back of neck. The Eustachian catheter is passed along the nostril and guided into the tube. A bougie (negative pole) is passed along the catheter and Eustachian canal until it meets obstruction. The current is then gradually turned on up to 4 milliampères, for about four minutes.

Lachrymal obstruction (stricture of canaliculus and duct).—Indifferent electrode positive, in convenient situation, probe negative, 2 to 4 ma. used.

Stricture of œsophagus.—Progressive electrolytic dilation with olive-shaped electrodes and feeble currents, as in the method of Newman for urethral stricture, has been tried in stricture of œsophagus, it is said, with good results.

Orchitis.—The positive electrode is placed under the affected testicle, the negative upon the spermatic cord, current 6 to 8 ma., which can be raised to 20 ma. if the electrodes are rather large. Treatment twice daily; duration, ten minutes. In chronic cases it is advisable to moisten the electrodes with solution of iodide of potassium and place them in front and behind the affected part. (Duboc.) Orchitis.

The cystoscope.—This consists of a tube with a bend at the end, in which, protected by a rock crystal window, there is a lamp. At the concavity of the bend there is a prism which enables a considerable amount of the bladder surface to be seen. At the back of the bend there is a simple glass The cystoscope.

opening which enables the posterior wall and base of the bladder to be seen. No. 22 French gauge is a convenient size.

For cystoscopic examination the bladder should contain five to eight ounces of clear water. Appearances will vary with the distance of the prism from the bladder wall. At 5 mm. it magnifies, at 20 mm. diminishes. The best distance is 10 to 15 mm. For practice with this instrument a dummy bladder is made. Cystoscope lamps take about 8 volts and $1\frac{1}{2}$ ampères.

The urethroscope.

The urethroscope.—By means of this instrument a long canal, such as the urethra, can be seen throughout its length, and by the aid of a cotton holder it is also possible to make an application to the exact spot. It is necessary to have tubes of various sizes to adapt to the instrument. An inflating arrangement is also supplied with the instrument. Tubes and funnels of different diameter can be screwed on for the illumination of the ear and nose. Lamps require about 9 volts and ·75 ampère.

The laryngoscope.

The *laryngoscope* has a small electric lamp placed in front of the mirror.

The *vaginal speculum* is also fitted with a small incandescent lamp; 7 volts and 1 ampère.

A useful forehead lamp is mounted on a steel band; it requires 8 volts and 1 ampère.

The electric probe.

Surgery owes something to electricity for the electric probe. The idea of using electricity for the detection of bullets embedded in the tissue seems to have originated with Professor Favre of Marseilles in 1862; but electrical exploration has not always proved a success. In the case of President Garfield an attempt was made to localise the bullet by means of the induction balance; but this was not successful owing, it was stated, to the unsuspected presence of some metallic substance about the patient's bed. In the case of Garibaldi it was not an electric but a porcelain probe which eventually decided the difference of opinion between the English and the French surgeon (Nelaton) in

favour of the latter. The bullet was found to lie between the tarsal bones, and was successfully extracted. It was de Wilde, a civil engineer, who (1872) first proposed the use of the electric bell as a signal of a metallic body in the tissues. An improvement on this is the telephone probe: its action depends on the difference of potential between two different metals, and upon the delicacy with which the telephone will disclose an electric current so engendered. A thin sheet of pure silver is placed upon an indifferent part of the body and attached by means of a wire having a tele-

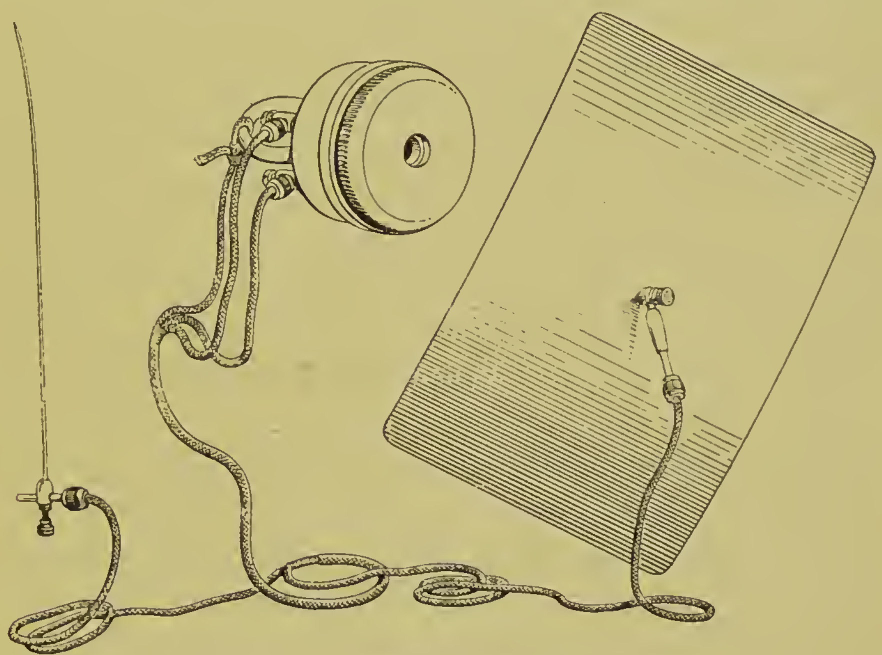

FIG. 90.—The telephone probe.

phone in circuit to a silver probe or heavily plated exploring needle. If the probe be inserted into the tissues the telephone is silent because there is no difference of potential that the telephone will register; but immediately a metallic body other than silver is touched there is a fall of potential, a current is produced, and the telephone indicates the fact. Used to verify the localisation of foreign metallic bodies whose presence has been shown by radiography, this probe is a strikingly effective device.*

* See paper by the Author, 'Electrical Review,' November 12th, 1897.

CHAPTER X

Cataphoresis

Historical sketch.

In 1807 Reuss demonstrated the electrical transfer of liquids through a porous septum. In 'The Annals of Philosophy,' 1817, Porrett showed that when a galvanic current is conducted through the living, fresh, sarcous substance, the contents of the muscular fibre exhibit a streaming movement from the positive towards the negative pole (as in all fluids), so that the fibre swells at the negative pole. The same thing, or something very like it, has been known, described, and discussed under many different names; "electric endosmose," "electro-capillary phenomena," "electro-vection," "electro-filtration," "anodal and cathodal diffusion." In 1833 Fabré Palaprat suggested the introduction of potassium iodide through the skin by this means. In 1845 Napier read a paper on the subject before the Chemical Society, and after him many observers, notably Wiederman, Freund, and Helmholtz, have studied its phenomena and announced its laws. In 1855 occurred the well-known incident related by Vergnés, the electro-plater of Havana. Having accidentally placed his hand in a bath prepared for electro-plating, he noticed a metallic coating on the negative electrode. He had at the time an obstinate ulcer on his hand, caused by his having frequently to dip the latter into solutions of cyanide and nitrate of silver and gold. Soon after the above occurrence the ulcer healed, and it was considered that the metal having been transferred from the ulcer had formed the deposit seen on the negative electrode. In 1859 Sir B. Richardson described a process of inducing anæsthesia by narcotics,

anodynes, and electricity, which he called "voltaic narcotism." Unfortunately, however, and now it would appear on evidence altogether insufficient, he abandoned his position. During quite recent years in Europe and still more in America the subject has excited renewed interest. In 1873 Professor Hermann Munk published a paper on the cataphoric changes of porous moist bodies, and on the galvanic introduction of various fluids into an intact living organism.* In 1884 Erb, Lewandowski, Boccalari, and others introduced medicinal substances into the body through the unbroken skin, and showed their presence in the urine and saliva. In 1886 Wagner † suggested the introduction of cocaine by the galvanic current, and in the same year Dr. Morton of New York turned his attention to the subject, and has steadily pursued it ever since. Attempts were made by Lewandowski, Lombroso, and others, to introduce chloroform in this way, but with indifferent success, due partly to the high electrical resistance of the chloroform and partly to the fact that dermatitis sometimes resulted. During 1888 and 1889 Dr. F. Peterson of New York proved that "current and cocaine together" will produce anæsthesia, and this only if the cocaine be placed at the positive pole. In 1889 Mr. Newman Lawrence and Dr. Harris read a paper on "Cataphoric Medication" before the Society of Arts, and Dr. Cagney brought the same subject before the Harveian Society. In 1890, at the Berlin International Congress, Mr. Edison read a paper in which he described the following experiment:—Two jars were arranged, one containing a 5 per cent. solution of lithium chloride with the positive pole in it; the other, a solution of common salt, contained the negative pole. One hand was placed in each jar, and a current of 5 ma. was passed for two hours a day for ten days. The urine collected showed distinctly the presence of lithium. In 1891 Morton described "anæmic cata-

* 'Archiv für Anat. und Physiol.,' 1873, Physiological Section.
† 'Wiener Med. Presse,' 1886, S. 212.

phoresis" in the 'New York Medical Journal.' His method was to cut off the blood-stream by an Esmarch bandage suitably applied to the part under treatment, thereby limiting the application to the area for which it is intended. In 1892 an interesting and instructive discussion took place at a meeting of the American Electro-therapeutic Association, when the subject was ably dealt with by Mr. Kenelly and others. Gärtner and Ehrman, by adding bichloride of mercury to an ordinary hydro-electric bath, through which a current of 100 ma. was passing, claim to have obtained the specific effect of the drug. In 1894 Dr. Morton read a paper before the American Electro-therapeutic Association on "Electric Medicamental Diffusion." In 1896 the same author described "electro-guaiacol-cocaine anæsthesia," and demonstrated the usefulness of cataphoresis in dental surgery for anæsthetisation of the gums, the treatment of sensitive dentine, bleaching of teeth, and sterilisation of the pulp cavity. In 1897 Fubini and Pierini, of Pisa, discussed the subject, and detailed much experimental work that will shortly be referred to.

Theory. *Electrolysis and cataphoresis distinct phenomena.*—The principles of electrolysis and cataphoresis have been to some extent dealt with at pp. 98, 99, 100. It has been explained that in electrolysis an electric double current is set up, the positive seeking element, the anion, going in one direction; the negative seeking, the kation, going in the other direction. It may be added that Kohlrausch discovered that each atom has its own rate of motion in a given liquid. This appears in the following table :

Speed of atoms when urged by 1 volt to the lineal centimetre of electrolyte :

Hydrogen	travels at	1·080	cm.	per hour.
Potassium	,,	0·205	,,	,,
Sodium	,,	·926	,,	,,
Lithium	,,	0·094	,,	,,
Iodine	,,	0·216	,,	,,

The facts of electrolysis do not seem adequate to account for the phenomena of cataphoresis, and it has been explained (at p. 100) that cataphoresis, or the mechanical transference of substances by means of the current (and usually *in the direction of* the current), is a property of the current coincident with electrolysis but not dependent on electrolysis, excepting so far as the latter is necessary to secure the passage of a current. In other words, the current once established allows the propulsion of *undissociated* molecules along with it.

From the medical standpoint cataphoresis presents itself under three heads: (1) The administration of medicinal substance by transference through the unbroken skin. (2) The streaming movement of the fluids of the tissues from one part to another under the directive action of a current, a phenomenon which must take place in every application of a continuous current to the body. (3) *Metallic electrolysis.* This combines two processes; the first refers to the electrolytic action at the positive pole, the electrode when metallic and not of platinum being itself attacked, and an oxychloride of the metal being formed, which (secondly) is driven on into the tissues under the directive (cataphoric) influence of the current. Medical uses.

1. *The introduction of drugs into the body through the uninjured skin.*—It has been shown by Fubini and Pierini, of Pisa, that for the introduction of some substances into the body it is necessary to have one direction of the current, for the introduction of others the opposite direction. The iodine of pot. iod., the salicylic acid of sodium salicylate and of lithium salicylate, and the arsenious acid of arsenite of pot. penetrate the organism when the negative pole is in the aqueous solution of these salts. The strychnia of strych. nit., the atropine of atrop. sulph., the quinine of quin. hydrochl., the cocaine of cocain hydrochl., the lithium of lith. salicyl. pass into the body when the positive pole is in the aqueous solution of such salts. Experimenting upon a piece of exsected muscle with 80 ma., Labatut succeeded "Cataphoretic medication."

16

in passing $\frac{6}{10}$ of the dissolved drug into the muscle within an hour.

Meissner has lately studied the subject, and the conclusions he arrives at are as follows: (1) Cataphoresis will take place from the positive pole only; (2) the electrode liquid must be a better conductor than the liquid within the tissues; (3) the current must be reversed every five minutes; (this is because the "secondary internal resistance," due to the drying up or "choking" at the anode, becomes so great that it prevents a continuation of the process); therefore (4) both electrodes must be moistened with the liquid to be introduced and the current reversed at intervals; (5) both electrodes must be placed as close to each other as possible. He uses as an electrode a shallow cylinder of vulcanite (Fig. 91) 3 cm. in diameter; this is divided by

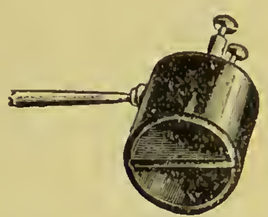

FIG. 91.—Cataphoretic electrode. (Meissner.)

a partition of the same material and the cylinder is closed at one end. Through this closed end pass the conducting wires terminating in binding screws. The two chambers thus made are filled with sponge or some suitable material which is impregnated with the liquid to be introduced. To save the trouble of reversing the current a clock-work arrangement is used which does this automatically every five minutes. This used with the above-described electrode the present writer has found convenient and effective. Its interior mechanism is shown in the following figure (Fig. 92).

The following are amongst the many drugs that may be used cataphoretically:

Ether, chloroform, aconite, strychnia, hydrochlorate of

eucaine, hydrochl. of cocaine, guaiacol, pilocarpine, menthol, strychnine, helleborine, pot. iod., aqueous solution

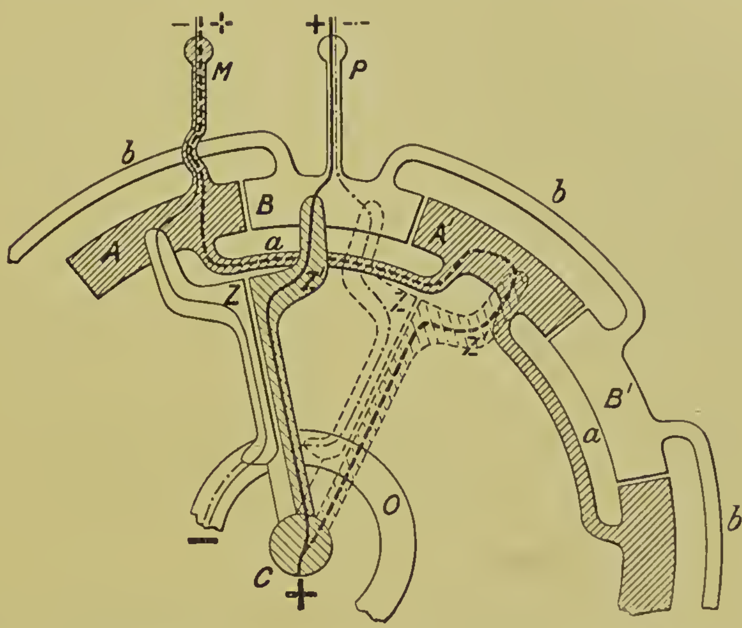

FIG. 92.—Automatic current reverser for cataphoresis. (Meissner.)

The current enters at C, passes through Z', and from it to B, thence to P, returning to M, thence passing through A and Z and from this to O, thence returning to the battery. If now we imagine five minutes to have elapsed the hand will have reached the position indicated by the dotted lines. The current coming from c now passes through Z' to A', thence through a to A and on to M and back to P; from P through B to Z, and through O back to the battery. Thus the current has been reversed, and this will occur every five minutes on the apparatus being put into action.

of iodine, bichloride of mercury, salicylic acid, salol, antipyrine, carbolic acid, pyrozone, nitrate of silver, chloride of sodium, chloride of zinc, &c.

The process may be carried out by means of electrodes covered with blotting-paper or other absorbent material applied to the skin, or by immersing parts of the body in medicated solutions, or by the general hydro-electric bath. As an example, take the localised application of cocaine.

To apply cocaine locally soak the positive pole covered with some absorbent material in a four to a twenty per cent. solution Cocaine anæsthesia.

of cocaine hydrochlor., and let the negative electrode of large size be applied to some other part of the body; use, say, 10 to 15 ma. for ten minutes to half an hour. Here the cocaine, taking the place of the alkali of the salt, passes from positive to negative electrolytically, according to the well-known law of the migration of the ions. At the same time a mechanical transference of the fluid takes place in the direction of the current—electric osmosis—and this as already pointed out, is perhaps the chief agent in the process.

Cataphoretic electrode. Cataphoresis is more easily and effectively carried out by means of special electrodes. Fig. 93 is one of many such

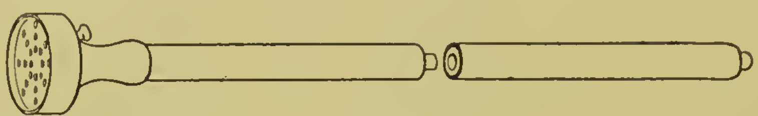

FIG. 93.

devised by Dr. Morton. It shows a metallic disc half an inch in diameter, perforated with a number of holes, with a reservoir at the back to hold a supply of fluid; the latter, trickling down, keeps moist the small piece of blotting-paper which covers the metal disc.* These discs vary, of course, in size; some may be six inches in diameter. Dr. Morton has constructed electrodes for the nose, ear, vagina, and for

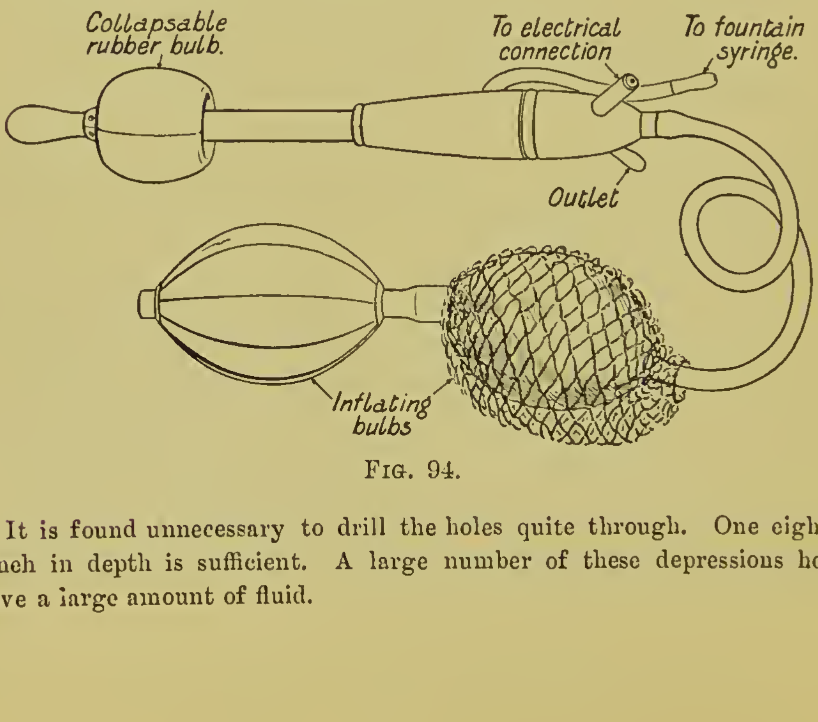

FIG. 94.

* It is found unnecessary to drill the holes quite through. One eighth of an inch in depth is sufficient. A large number of these depressions hold in reserve a large amount of fluid.

use in cases of skin diseases. Fig. 94, taken from Dr. Morton's book, shows an electrode for cataphoretic applications to the uterus and appendages. "It consists of a long, hollow tube with a perforated nozzle on the end, and a collapsing rubber bulb near this nozzle. Ordinarily the bulb is collapsed, and can readily be introduced into the vagina. If the inflating bulb is attached to the central stem at the right, and a slight pressure exercised, the bulb in the vagina is more or less inflated and acts as a perfect stopper. Medicated solutions can then be introduced into the vagina from a fountain syringe, and the current being turned on at the connecter shown at the right, passes through a wire or rod to the inside of the nozzle where it is effective upon the solution electrode or medicated solution inside the vagina." The fluid can afterwards be withdrawn through a valve shown in the drawing. The local hydro-electric bath is a convenient way of securing "medicamental diffusion," tubs or other vessels being used for the feet and legs and basins or jars for the hands and arms. In the vessel containing the medicated solution the positive pole (carbon) is placed. (See Hydro-electric Bath.)

In skin disease, syphilis, and such conditions as are usually treated by iodine, the cataphoretic application of potassium, sodium, or lithium iodide is useful. Articular affections of a gouty or rheumatic character can be effectively treated by this means. The following is a case of Dr. Morton's :—

Case.—April 13th, Mrs. S. A. A—, æt. 45, gouty knuckles, deformed; pain of ten years' duration. Rubber umbrella rings were passed over the fingers to cut off the circulation (like an Esmarch's bandage), thus causing the solution to act only on that part of the body for which it is intended. The fingers were then dipped up to the level of the rings in a solution of bromide of lithium; positive electrode 5 ma. for fifteen minutes in the water. Great relief for twenty-four hours. April 30th, May 3rd, 5th, and 7th same treatment, but on May 5th a saturated solution of piperazine was placed upon blotting-paper, wrapped about the distal joint of the index finger (the joint most affected), and a piece of platinum foil wrapped

about the blotting-paper as a positive electrode; 10 ma. ten minutes. May 9th.—Joint better, softer, smaller. June 2nd, lithium and piperazine treatment continued until this date, when tetra ethyl ammonia, a few drops on blotting-paper, was substituted for piperazine. Knuckles now show scarcely any trace of enlargement.

The chloride, benzoate, and citrate of lithium are all very soluble salts, and may be used with the positive pole in the above manner. The mercurial salts and aqueous solution of iodine are suitable. For the application of anæsthetics, astringents, or antiseptics, and in treatment of the upper air passages, &c., the method will be found useful. (Morton.)

Cataphoretic local anæsthesia.—With an electrode one inch in diameter, a current of 8 to 10 ma., and an 8 per cent. solution, ten minutes is required to produce anæsthesia. The combination of guiacol with cocaine is more convenient and effective :—

Guaiacol (pure) ... ʒj.
Cocaine Hydrochl. gr. vj. (Morton.)

The strength of the solution may be increased to 30 per cent.

CASE.—December 3rd, Mr. D. D. S—. Lupus; ulceration involving angle of mouth over an area of two inches. Also separate nodule, size of bean, on lower lip. Three applications of guaiacol-cocaine, 8 per cent. solution, 1 inch electrode, 4 ma., five minutes; profound local anæsthesia. Entire area treated with copper bulbs, half an inch long and a third of an inch wide, positive pole, three applications. Complete cure.

In the absence of special electrodes, any flat nickel-plated electrode, covered with blotting-paper to absorb the medicated solution, may be used. For convenience, and in some measure to ensure accuracy of dose, cataphoretic discs are prepared, *e. g.* menthol, 2 gr. ; helleborine, $\frac{1}{25}$ gr. ; strychninæ nit., $\frac{1}{32}$ gr. ; iodol, 2 gr. ; corrosive sublimate, $\frac{1}{8}$ gr. ; cocaine hydrochl., $\frac{2}{5}$ gr. ; aconitine, $\frac{1}{64}$ gr. ; pot. iod., 4 gr. ; lithium chloride, 4 gr. The object of using large electrodes such as baths, local or general, is to secure, not a greater extent of mere surface, but a larger number of pores or

channels, as well as to obtain the advantage of being able to use a large current, yet not too dense for easy tolerance. It may be repeated that the amount of material transferred is in proportion to the number of pores or channels, as well as to the intensity of current and the "resistivity" of the solution.

Porret's phenomenon.

The "*streaming movement*" of the fluids under the directing influence of the current (Porret's phenomenon) is probably a factor in the different physiological effects of the two poles of a continuous current, but what share it takes in producing these effects is not definitely known.

Metallic or "interstitial" electrolysis.

"*Metallic*" *electrolysis.*—The object of this form of cataphoresis is to secure, not so much an electrolytic effect on the tissues, as the electrolytic dissolving of the electrode itself, and the diffusion of the newly-formed salt into the tissues. For example, if a copper electrode be used the metal is oxidised and chlorine is evolved from the decomposition of the tissues; this forms with the copper a secondary salt, the oxychloride of copper, which diffuses into and over the affected part by the cataphoretic action of the current. Ozæna, obstinate post-nasal catarrh, tonsillitis, nævi, lupus, sinus, and fistula have been successfully treated in this way. It is to Dr. G. Gautier that we are chiefly indebted for this method. Its *rationale* rests on the following considerations: If electrolytic decomposition of the tissues of the body be effected by a non-oxidisable electrode such as platinum, there appears, as we know, at one of the poles bases and hydrogen, at the other acids and oxygen. The nascent bodies liberated at the electrodes act upon the tissues, even cauterising the latter if the current be strong enough. But if the decomposition in question be effected by a positive electrode such as copper, which is susceptible to electrolytic action, there is obtained a nascent body, oxychloride of copper ($CuCl\ 2CuO$), which will act upon the tissues in its own way. It is such secondary electrolytic actions that are the great feature of metallic or "interstitial"

electrolysis. The oxychloride of copper penetrates the tissues, and its action will be the more energetic in proportion to the duration and intensity of the current, and the extent of surface acted upon. Metals other than copper may be used as the oxidisable electrode—zinc, iron, manganese, aluminium—but copper seems to be the most generally useful. These "soluble electrodes" are usually either in the form of needles or bulbs.

CASE.—*Follicular tonsillitis.*—October 18th, B. G. A—, æt. 15. Throat began to be sore two days previously; painful and swollen. Malaise and nausea; tonsils enlarged, greyish-white spots on both. *Treatment.*—Electric diffusion from copper electrode to every spot. Oct. 20th.—No more trouble with throat. (Morton.)

Cataphoresis in dentistry.

In *dentistry* cataphoresis has been most successful in Dr. Morton's hands for anæsthetisation of the pulp, the treatment of sensitive dentine, and other purposes. Fig. 95

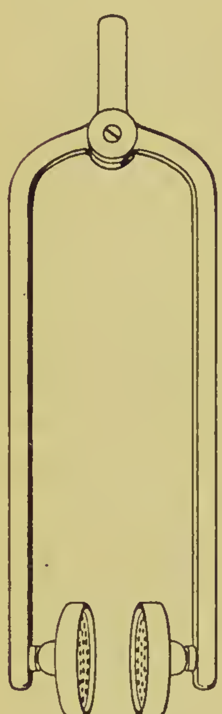

FIG. 95.

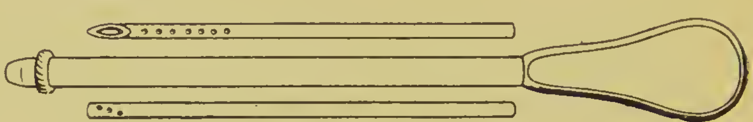

FIG. 96.

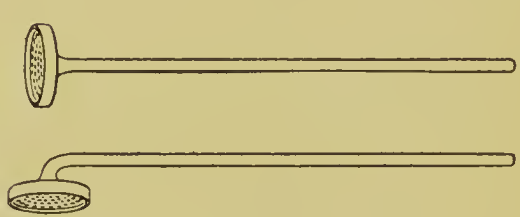

FIG. 97.

shows the tongs-shaped duplex cataphoric electrode for application to the gums used by Dr. Morton. He finds that eight minutes with an 8 per cent. guaiacol-cocaine solution,

diluted with half its quantity of almond oil, is suitable. For application to smaller cavities the tubular perforated electrodes (Fig. 96) may be used. For larger cavities the perforated electrodes shown in Fig. 97 will be found suitable. For sterilisation of the pulp cavity and dentine, and the treatment of alveolar abscess, the hypodermic syringe electrode may be used. A strong aqueous solution* of peroxide of hydrogen is mentioned as an agreeable antiseptic. This method may be also applied for bleaching teeth. Apply the solution by the positive electrode to the tooth which is to be bleached. The negative electrode having been applied, gently turn on current, and before the milliampère registers the patient may complain of pain. Leaving the current as it is the pain will pass away and the current can then be increased to ·5 or 1 ma. This will serve to pass the pyrozone into the dentine (which is a conductor) if the enamel (a non-conductor) is broken at any part. Metallic stains cannot always be removed.†

Mercurial cataphoresis.

The cataphoretic administration of mercury has been elaborated by Massey. His method is to "amalgamate" gold electrodes with this metal, *i. e.* to cause the mercury to adhere to the electrode surface by first dipping the latter into weak acid, and then into mercury. Employed as a positive pole the mercury dissolves (together with probably a minute quantity of gold), being united with the atoms of oxygen and chlorine, produced at this pole by electrolysis of the tissues, to form oxychlorides, which, as already said, are diffused by the cataphoretic procedure into the immediate neighbourhood of the electrode along the line of current flow. Pursuing this subject Dr. Massey goes on to say ‡ that, whilst the active

* A 25 per cent. aqueous solution of pyrozone or dioxide of hydrogen may be thus prepared:—Take a glass tube and 2 cubic c.m. of pyrozone, 25 per cent. ethereal solution, add a cubic c.m. of water. Mix in the tube and place in an evaporating dish, and in three or four minutes there is left an active watery solution of pyrozone. (Morton.)

† It is obvious that cataphoresis supplies a method of staining tissues (see Dr. Morton's book).

‡ 'Conservative Gynæcology.'

part of sarcoma and carcinoma can be destroyed by cataphorically impregnating the tumour with nascent oxychloride of mercury in sufficiently massive doses, the cancer-holding tissues are not killed. He considers that the current carrying onwards the drug, can be made to follow the paths of proliferation, which, owing to the cellular nature of the structure, are really the lines of lowest electrical resistance. He considers also that the cancer tissue has less "physiological resistance" than the other tissues, for it is found to lose its vitality at some distance from the electrode without being accompanied by necrosis of the healthy tissue. The mercury-coated electrode not furnishing a sufficient supply, it was necessary to secure a large quantity of mercury at the active surface of the gold. Dr. Massey therefore has the instrument made hollow and perforated at the active extremity, in order that the mercury may be injected freely about the active surface of the electrode. Before the current is turned on, a small glass syringe is used to inject the mercury through a soft rubber tube. The battery ought to have an E.M.F. of 150 volts. As the indifferent electrode, a lead plate is used about 12 × 50 cm. with a binding post for attachment to the negative pole. This plate lies over a thick pad, well soaked in hot water, and extending beyond the edges of the plate.

Full anæsthesia having been produced and the patient laid on a table, this pad is applied and pressed against the body, the greater part of the pad being behind the hips and against the thighs. With a narrow bistoury a slit should be made in the tumour and an electrode thrust in near its base. Having inserted the electrode or electrodes, mercury should be injected through them into the surrounding tissues. The intensity of the current and the duration of the application must depend upon the size of the growth. Dr. Massey says that the current used has varied between 350 and 1200 ma., and the duration of the application between fourteen minutes and half an hour. No increase of current

will make up for a lack of penetration due to insufficient duration. The aim is to accomplish complete results at the first operation, although a second may be undertaken after a month. Almost immediately the current is turned on, a blanching and shrinking becomes evident, then around each electrode a greyish necrotic area forms. On recovery from the ether a certain amount of pain is felt for several days. This requires morphia. There is an irritation of neighbouring tissues, but this passes away in a few days and freedom from pain ensues. The tumour is dressed with dry acetanilid powder and absorbent cotton daily. After being cleansed from the grey discharge and excessive mercury, the wound becomes clean and ready to heal by granulation in a fortnight to three weeks.

The milder method is that already detailed by amalgamated electrodes; anæsthesia is not employed. In this case a whitish eschar forms, which becomes an extensive slough if strong currents are used. Currents for this purpose rarely exceed 50 to 80 ma. Other details as in the major method. The minor procedure can be used daily or as often as possible until a cure is effected. It is suitable for small local growths and in cavities which can be seen directly, but it is always inferior to the more thorough operation.

The above details with reference to "mercurial cataphoresis" are taken from the writings of Dr. Massey, who considers that he has obtained encouraging results, and they are here given at some length on account of their interest and novelty. The present writer is not in a position to add his personal experiences.

CHAPTER XI

The Hydro-electric Bath

What proportion of current does the patient receive?

The body's share of current.—The first question is this:—With a given current running through a given bath what proportion of such current will find its way through the body of the immersed patient? This question may be answered as follows:—The patient's share of the current will vary with the specific resistance of the water, *i. e.* its temperature, &c., with the total volume of water, the volume and resistance of displaced water, the specific resistance of the immersed body, and the position which the latter occupies relatively to that of the water. But under the usual working conditions it will be safe to say that the *average* current passing through the body is about 25 per cent. of the total current running through the bath; and that the *maximum* current through the body is probably nearer 50 per cent.,—that is, through the trunk; whilst at the ankles, a part of the body which would occupy only about one fiftieth part of the sectional area, the current flowing might be only about four per cent. of the total.*

Construction of bath.

The substance of which the bath is made must clearly not be metal. Oak or porcelain is the most suitable material. Insulation must be carefully attended to, both of conducting wires and waste pipe; the latter being insulated from earth by a short length of rubber tubing let in near the bath; or better by having the discharging orifice of the bath "overshot" over a sink.

* See 'Hydro-electric Methods in Medicine,' by W. S. Hedley, M.D. Lewis: London.

The following are suitable dimensions for the bath:—length, 140 cm.; width at widest part, 71 cm.; height at top, 54 cm.; height at bottom, 38 cm. Area of electrodes: anode, 462 sq. cm.; cathode, 462 sq. cm. Sides and ends in both baths are perpendicular.

The present writer advocates the use of a "cervical" and "lumbar" electrode, the dimensions of each being about 25 × 15 cm. These can be used separately or together. At the foot of the bath there will be a terminal or foot electrode of slightly larger dimensions than the cervical or lumbar. The two last named can be used as a right and left "lateral," and one of them, covered by a light wooden framework, may at other times be utilised as a "guteal" electrode upon which the patient sits. The only further addition, a very useful and even necessary one, is the so-called "paddle electrode." By means of a long insulated handle such an electrode can be applied to the vicinity of any part of the body upon which it may be desirable to concentrate the current. Suitable dimensions for this electrode will be 12 × 18 cm. These electrodes are all removable from the bath, and can be arranged as desired for each particular treatment. A number of fixed electrodes, several of which are "idle" during treatment is not desirable from an electrical point of view. Why? Consider a cross section of the bath at the position occupied by the trunk, and assume the resistances of the body and water at that place to be each 50 ohms (of course, they are in parallel); now place also in parallel with them an "idle" metal electrode having a resistance of 1 ohm. It will be readily seen that the body and water are, to all intents and purposes, short-circuited, and that practically the whole of the current passes *viâ* the "idle" electrode. Unless, therefore, it is purposely intended to "shunt" the current past a certain portion of the body, no other electrodes than those actually in use should be allowed to remain in the bath.

It has been proposed by Gärtner to insert a partition or

diaphragm (through which the body of the patient passes) across the bath. Now, supposing that the junction of the body with this partition approach the condition of a "water-tight joint" it is evident that practically the whole of the current passing through the bath must pass through that part of the patient's body which is in contact with the partition, no other route being open. But it is through this particular part of the body *only* that the entire current will pass. Is such a result desirable? It is obvious that an arrangement of this kind represents either a disastrous concentration of current on one particular part, or an inadequate current for the rest of the body.

The electric bath is correctly and conveniently spoken of as "monopolar" and "dipolar."

Monopolar bath.

The monopolar is that form of bath in which one electrode only is in the water; the other being applied to some portion of the patient's body (neck, arm, hand) out of the water; and this will be the point of entrance or emergence of the current, *i. e.* it will be the anode or cathode according to circumstances. The opposite pole is the whole of the patient's body in contact with the electrised water; or, in other words, the water in contact with the body constitutes one huge electrode, adapting itself accurately to every irregularity of surface, and carrying a very widely diffused current.

Dipolar bath.

In the *dipolar* bath both electrodes are in the water, *i. e.* the current is led off from both poles of the battery, or coil, or current controller, direct to the water; a current being thus applied to the patient's body only through the medium of the water. For most purposes of general electrisation this is the form usually preferred.

Temperature of bath water.

Temperature and other points.—The temperature of the bath may be between 90° and 98° F. (32° to 37° C.).

Precautions.

Precautions.—The ordinary rule of not taking a full bath after a meal ought to be followed. In the case of insane, anæsthetic, paralysed, or other helpless people, special precautions must be used. Not only must the greatest care be

exercised in placing the patient in the bath, but ulcerated surfaces, skin abrasions, or other wounds must be looked for and protected from the action of the current, by sticking plaster, collodion, or other means. The patient's "sensibilities" must also be examined. It is within the present writer's knowledge that in the case of tabetics, who were also anæsthetic, serious ill-effects have followed the administration of electric baths by incompetent persons, whose only idea of current strength seemed to be the limit of the patient's endurance.

The patient having entered the bath, the current will be turned on and very gradually brought to the strength required; but if the operator have any doubt as to the accuracy and smoothness in working of the current regulator, it will be found a useful precaution to let the patient sit towards the middle of the bath with his back some distance from the upper electrode and his feet drawn up from the bottom one, and from this position gradually to extend himself after the current is made.

Polarity of the bath.

Direction of current flow.—The question of polarity will have to be decided on general principles, or more probably by a careful trial. The late Dr. Steavenson states that the direction of current flow should "generally be from the feet to the head." No reason seems to be assigned for this rule, and it is not quite easy to feel satisfied of its usefulness. At the same time it is necessary always to bear it in mind as being the opinion of a high authority and the outcome of a large experience. The necessity for a very gradual making and breaking of the circuit, unless when the special effects of sudden rupture or reversal are desired, are amongst the things common to ordinary electrical applications, and need not be insisted on here. If a continuous current be running, the galvanometer and the patient must both be carefully watched. If an alternating current be in use, and no measuring instrument in circuit, the operator will not only regulate strength by the arrangements of his

coil, or transformer, or by his rheostat, but will also from time to time estimate its strength by his hands extended in the water to the extreme ends of the bath.

Duration.

Duration.—The period of immersion will usually be fifteen or twenty minutes, and will only on rare occasions exceed or even extend to half-an-hour. The first bath of a series ought to be more or less an experimental one, and of even shorter duration than the first-named time. As the patient emerges from the bath, and stands up in the water, a cold affusion in some form or a mild faradic douche may be administered, according to individual toleration. The patient who finds it necessary to undergo a course of electric baths has not generally any considerable resisting power to cold. He is moreover often nervous and hypersensitive. Therefore, if stimulation either by the cold affusion or by the electrised douche be attempted, it is imperative that the operator have his apparatus well in hand; that in other words he must be able easily and accurately to regulate both its electric and its hydriatic strength. The light bathing dress is now removed, and after vigorous friction the clothes are resumed and a quarter of an hour's rest is taken. Then, weather and strength permitting, the patient walks, part at least of the distance, home.

Physiological effects of the bath.

Physiological effects.—The physiological effects of the electric bath are thus summed up by Erb :—" Respiration diminished by dipolar, temperature slightly lowered by monopolar, metabolism promoted considerably by dipolar, slightly by monopolar, and secretion of urine increased. Appetite and digestion are improved, the genital functions are stimulated, circulation and nutrition are benefited, sleep notably restored, and new vigour imparted to the mental and physical faculties. In short, the electric, and especially the faradic, bath is credited by all with a powerful invigorating and refreshing action upon the human frame." All who are conversant with the subject will recognise the accuracy of this general statement, but it is scarcely necessary

to say that a good deal has been learned about the electric bath since this was written.

Therapeutic effects.—Speaking broadly, the painless and evenly-distributed current of the general electric bath makes it one of the best methods of electrisation, with, at the same time, a considerable power of concentration on special parts according to the indications of the case. In all states of general debility and impaired nutrition (Erb), in weakness or exhaustion of the spinal nervous system, "nervous dyspepsia," palpitation, hysteria (Erb), neurasthenia, and many of those diseases referable to some derangement of the nervous system without appreciable lesion, commonly called neuroses, it may be resorted to with excellent and unique results. Neuralgias, sciatica, paralyses both of central and of peripheral origin, chorea, primary lateral sclerosis, muscular rheumatism, gout, rheumatoid arthritis, and occasionally chronic articular rheumatism, are all recorded to have been cured or alleviated by its use. It has been used with good effect in some irritative conditions of the spinal cord, in alcoholic or mercurial tremors, plumbism, and even in paralysis agitans (Lehr, Erb), and in peripheral neuritis, from whatever cause, although not in the very early stage. There may also be enumerated the excellent results (of the faradic bath) recently recorded by Segretti in the treatment of rickets. In connection with the alternating dynamo current bath very special attention must be drawn to the still more recently recorded experiences of Gautier and Larat, not only in many of the above conditions, including rickets, but also in "strumous" conditions, obesity, eczema, and many so-called diatheses, and diseases due to failure or perversion of nutrition.

Therapeutic effects of the bath.

For the continuous current bath twenty Leclanché cells will be required, with a rheostat, or a cell collector. If a dynamo current is used it will be controlled as described in "Current from the Main;" 25 to 200 ma. may be the total current running through the bath according to the purpose

Continuous current bath.

required. The duration of the first bath will be eight to ten minutes ; after that it may be gradually increased to fifteen or twenty, or even more.

Details of the physical character, and the chemical and physiological effects of the continuous current circuit from lighting stations, as well as the best means of regulating it, will be found in the chapter on "Current from the Main." *

Electric lighting currents as source of supply.

In using public supply currents for the purpose of the electric bath, the first consideration must be the paramount necessity for efficient insulation ; and this necessity will apply equally to all systems of supply, whether continuous or alternating, direct or transformed. In the usual electrical applications security would be attained by standing on a very dry floor, or, more certainly, on a varnished kamptulicon mat. But in the case of the water bath, connecting as it does with a good earthing device in the shape of waste-pipes and water pipes, the case is altogether different, and certain additional precautions then become necessary. With these duly carried out effective insulation can certainly be secured. In the first place it is obvious that the bath should not be made of metal. Hard wood or porcelain are suitable materials, the latter by preference. The bath should stand upon glass mushroom insulators filled with a heavy resinous oil (similar to those used for insulating storage batteries) or it might be placed upon hard vulcanised rubber blocks. The inlet stop-cocks for both hot and cold water should be placed at some distance from the bath, and in such a position that it would be impossible for the patient, when in the bath, to accidentally make contact with them. An insulating piece of porcelain or vulcanised rubber should be inserted in both inlet pipes between the stop-cocks and the bath. If the waste-pipe be attached to the bath an insulating piece should be inserted as close to the bath as possible. But danger may be even more easily and effectually averted by fixing directly below the waste outlet of the bath a shallow tank or sink

* See also "Current from the Main." London: H. K. Lewis.

to receive waste water from the bath, the waste-pipe being attached to this sink. Neither the tank nor the waste-pipe should make contact with the bath.

The diagrams (Fig. 98, p. 264) show the electrical conditions that exist—for example in a bath—when an earth connection is made; and illustrate the serious danger to which a patient would under such circumstances be exposed.

115 volts is the full pressure of supply. There is one "series" R = 80, and there are two parallel branches (R = 600 + 2 + 10 and R = 1). Then the total resistance $= \frac{612 \times 1}{612 + 1} + 80 = 80{\cdot}998$, and the total current $\left(\frac{115}{80{\cdot}998}\right) = 1420$ ma. The current in the respective parallel branches will be as 612 : 1—in other words, current being inversely proportional to resistance, and the milliampèremeter being placed in the circuit of higher R (in the proportion 612 : 1), only 2·3 ma. will be registered, whilst the remainder of the total current (travelling *viâ* the circuit of low R, viz. the earth) amounts to 1417·7 ma., and the milliampèremeter fails to register any of this leakage current. But both circuits are common to the bath. Had the patient been placed in contact with the uninsulated (neutral) wire and the resistance been interposed between him and the insulated pole (positive or negative) he would not, even if placed in an uninsulated bath, have been in the circuit of any earth current. This would hold true only so long as the condition of the mains was good. Should a fault break out on one of the outer wires (positive or negative) the state of affairs would be in no way different from the case just considered. What then is the remedy for this risk? Clearly insulation. It should be taken as an axiom that the current from public supply mains should *never* be applied either as a shunt or direct to the patient, without interposing between him and the earth an insulating substance of such a nature as would undoubtedly stand the

full main pressure across it without passing a current of 1 ma. In the case of three wire systems the "full main pressure" would be double that of supply, and in five wire systems four times that of supply. In dealing with public supply currents for medical purposes, the first and last word must be always *insulation*.

Faradic bath.

For the faradic bath a coarse but very effective form of bath coil known as that of Constantin Paul is commonly sold; it consists of a primary wire only. The regulation of strength is effected by means of a pivoted arm touching studs, and thus "tapping" various length of the coil wire. There is also a "shielding tube" which by its withdrawal increases the strength of the current.

Alternating light currents as a source of supply for the bath.

Alternating currents from light circuits.—The effects of sinusoidal currents, or rather of those pseudo-sinusoidal currents obtainable from alternating light mains applied through the medium of the water bath, have been specially studied by Gautier and Larat, from whose writings the following remarks are chiefly taken:—Immersion varies from a quarter of an hour to forty minutes, and beneficial results soon show themselves in an increased appetite, a general feeling of lightness and elasticity, and often in an improved action of the intestinal canal. These authors therefore regard such applications as a good general stimulus to the functions of organic life—a "tonic" like fresh air, salt water baths, or hydro-therapeutics. This general tonic action, they state, is especially seen in chlorotic anæmia, where even after four or five baths appetite returns, the enfeebled intestine resumes its normal functions, palpitation and bruits disappear, and menstruation is re-established. Equally noteworthy is this tonic action in that form of neurasthenia known as "spinal;" the characteristic feebleness of the limbs, girdle pains, and weakness of the genital organs, often quickly and permanently disappear. But a great deal more is claimed for this bath than a mere tonic effect. In disordered states of nutrition and in certain

"diatheses" the effect is to restore function to its normal type. This is effected partly by the tonic influence already noticed, and still more by that demonstrable increase in the nutritive exchanges which follows the treatment. In "strumous" conditions, both of children and adults, there is often a remarkable improvement. The same, and with even greater truth, may be affirmed of rickets. The authors in question regard rickets, not as a chemical derangement primarily affecting the bones, but rather as a condition dependent on faulty assimilation. And they come to this conclusion, inasmuch as by the treatment in question, rickety children, without the use of lime or iron, show a manifest improvement, the possibility of which no one can doubt after the demonstrations of Segretti. The latter used the extra current of the faradic machine. But the same effects are not less marked with the bath through which sinusoidal currents are passing. In cases of obesity, the treatment by the latter method has been followed by improvement in health and decrease in weight, often permanent. Four cases of muscular atrophy of myopathic origin are recorded which underwent improvement by the same treatment. Rheumatism, especially in its muscular manifestations (lumbago and torticollis), was cured by one or two *séances*. Neuralgic pains of a rheumatic character, especially sciatica, do not show so rapid an improvement, but still no treatment presents better results. In simple sciatica, cure is relatively rapid (fifteen to thirty *séances*), a result which the writers consider good, in view of the fact that in all the cases given the sciatica had proved rebellious to other forms of treatment. In subacute and chronic rheumatism the painful articular swelling and muscular weakness and atrophy that characterise these conditions often yield to this form of bath. The same may be said of gout. When the attack ends the pain and swelling disappear much in the same way that they disappear under the use of the thermal waters of Aix-les-Bains, and if the

treatment be carried out between the attacks the intervals become gradually longer and the attacks gradually shorten. Perhaps the most remarkable result that followed this form of alternating current bath was seen in eczema. In the case of a lady who was under treatment by these baths for chronic rheumatism, but was also suffering from an eczema of thirty years standing, it was noticed that the latter got rapidly well. The same has since been observed in a number of other instances, and relapse is rare. The good effect in such cases must be dependent on improvement in the general nutrition of the body rather than on any local action in the affected part, inasmuch as the bath led to disappearance of eczema of the face equally with those parts of the body to which the current had direct access. Similar results, but less constant in their occurrence, have been observed in urticaria.

The Electric Douche

The apparatus consists of a short length of flexible rubber tubing, having an inside conducting wire, one end of which is brought out and connected to a terminal about two inches from the brass union which joins on to the supply pipes. The two inches of rubber tubing thus interposed between the metal pipes and the conducting wire act as effective insulation at this end of the arrangement. The other end of the internal wire is soldered to the inside of the metal screw, to which different nozzles may be attached. The nozzles are of two kinds, one a single "jet," for current concentration, the other a "rose," for current diffusion.

By the use of such an apparatus it has been found that, with the ordinary domestic water supply, continuous current of useful strength may be passed with an E.M.F. of 50 to 60 volts from a battery of forty Hellesen cells when the nozzle is held several inches from the patient. Alternating

currents from a fair-sized bath coil pass through a much greater distance. If saline or other special conducting fluids be used, the distance through which the current passes is, as might be expected, much increased.*

The electric douche presents itself as a means of general electrisation by bringing the various parts of the body successively under its influence. It claims an action that may be strictly localised, and further offers itself as a means of producing, through various motor, inhibitory, and secretory reflexes, those influences on nervous centres and glands which can undoubtedly be brought about by other and more painful methods of peripheral electrical excitation. Used in this way, it will not fail to prove itself a nervine tonic "heightening cutaneous sensibility and quickening motor excitability." It will influence nutrition and absorption by its control over the distribution and circulation of the blood current. It will act favourably on local diseases, such as chronic joint affections, and promote absorption through its influence on the circulation. Its usefulness in states of general debility and malnutrition, neurasthenia, spinal debility, exhaustion, and any case in which want of "tone" is the prominent feature, needs no showing. These effects will be brought about in more ways than one, partly by the ordinary action of an electric current passing through the body, and partly by the enormous range of reflexes that by so effective a method of cutaneous stimulation are brought into action, and not at least, perhaps, by the direct neural connection known to exist between special skin areas and internal organs.

Its adaptability to some forms of internal application cannot fail to suggest itself.

Recent therapeutic experiences of the writer leave no doubt in his mind as to the usefulness of the electric douche. He has called it into requisition for the peripheral part of

* See 'Hydroelectric Methods,' by Dr. W. S. Hedley (Lewis).

the treatment of old-standing paralyses of central origin. He has found it a most useful adjunct to other electrical methods in the treatment of that ensemble of symptoms known as neurasthenia, and in cases of anæsthesia it has been found of the greatest service.

CASE.—B—, æt. 30. Paralysis of two months' standing, right forearm extensors and supinators involved, wrist drop, R.D. sensation impaired, "woolly" feel and numbness, especially over the distribution of the radial. One or two painful points in the course of the posterior interosseous. History and symptoms show it to be a case of pressure paralysis (muscular spiral). Was attacked shortly after having lain in an awkward position during several hours when intoxicated. Has taken medicine for two months. Electrical treatment now entered upon by weak currents ($\frac{4}{16}$), anode stabile on each painful point, five to ten minutes, cathode large indifferent electrode. After two or three weeks no improvement; at the end of one month (twelve sittings), slight improvement perceptible. Powerful peripheral stimulation was then resorted to, at first by "single pole" treatment, that is to say, the patient, being insulated and holding one pole of a large coil, had sparks taken from the arm. This was alternated with the electrised douche, and improvement followed with surprising rapidity, the cure being complete in eight weeks (twenty-five sittings) from the commencement of electrical treatment.

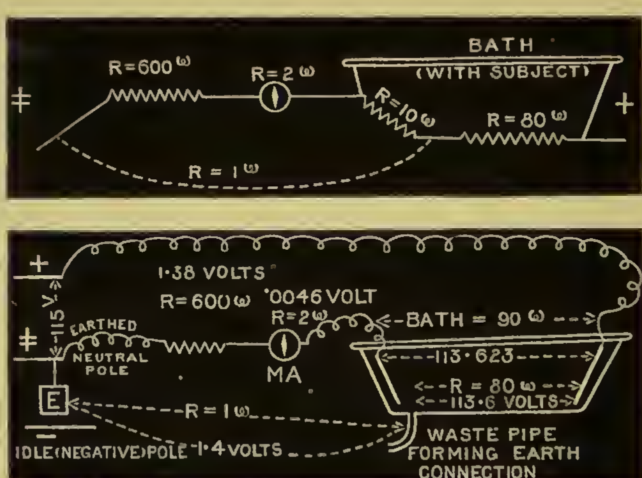

FIG. 98.—Diagram showing the electrical conditions that exist in a bath when an earth connection is made (see p. 259).

APPENDIX

Testing for Faults in a Circuit

How to test for current.—Take one cell with current selector, or if working with a rheostat, set it for small current; then bring the metal ends of the conducting cords together, and if the galvanometer shows no deflection there is a break in the circuit somewhere. The tips of the conducting cords applied to the tongue also reveal a current by the peculiar taste.

To localise the fault.—Attach one end of a wire to one terminal of the battery, and the other end of the wire to the other terminal. In other words, short circuit the battery through a wire, throw in one cell or arrange rheostat for small current. If now there *is* a deflection the fault is in the conducting cords. Ascertain which cord by using each in succession to short circuit the battery, instead of doing so by the wire. If there was no current on testing with the wire, try each particular cell of the battery by throwing one cell at a time into circuit by means of the double cell collector, and note whether or not there is a deflection of the galvanometer on trying any particular cell. If any cell is thus discovered to be at fault its condition and connections must be examined. A loose screw is often the cause of a break in the circuit. If no current can be got from any cell the screws that fix the current selector and current

reverser on their axis must be examined. These screws sometimes work loose, so that contact is not secured.

To localise faults in the induction coil circuit.—If the coil does not work first try whether the cell or cells which "drive" it are giving current. This is done by taking out the cell and noting whether there is a deflection on the galvanometer. Or it may be that the cell is giving current but is too far exhausted to furnish the electro-motive force necessary to actuate the coil. This can be ascertained by comparing the current sent through a certain resistance with a current sent through the same resistance by a cell known to be fully charged. If the cell is found to be in good order examine *the interrupter*; the latter sometimes requires a slight touch to set it into action. The hammer should be one sixteenth of an inch from the small electro-magnet, and the contact screw should just touch the platinum point. In those interrupters that have the hammer attached to a spring, the latter is apt to get out of order. If neither cell nor interrupter are at fault, the connecting cords must be examined. This is most effectually done by using well-soaked electrodes and placing the body in circuit.

To localise a fault in a cautery battery.—If the burners do not incandesce, note whether the copper wires that carry the current to the burner have got very hot. If this has occurred it is because they have got too near each other and current passes from one to the other without reaching the platinum burner. In such a case the wires must be separated. If the platinum burners seem in good order, detach the conducting cords from the cautery handle. If there is a spark on bringing their ends together the fault must lie in the handle, not in the battery. It is probably "the contact," *i. e.* the point where current is made and broken, that has become oxidised. If there is a weak spark it shows that the connecting cords are not at fault, but that the battery is run down and requires re-charging.

To test the polarity of electrodes.—Use pole-finding paper or place the tips of the connecting wires in a solution of Pot. Iod. In the former case the positive pole marks a red stain owing to acids; in the latter the brown colour of the iodine reveals the positive pole. The poles may also be distinguished by the larger volume of gas given off at the negative; the proportion of hydrogen at the negative to oxygen at the positive being as 2 to 1. A useful pole-finding paper is made by dipping blotting-paper into a solution of sulphate of soda to which a little phenol-phthalein has been added. Once dry, this paper does not deteriorate. To use it, wet the paper and apply the metal tips of the conducting cords. The magenta colour reveals the negative pole, and is due to the action of the phenol-phthalein in the presence of an alkali. In the acid and neutral states phenol-phthalein is devoid of colour.

To show the necessity for moistening the electrodes.—With a given E.M.F., *i.e.* with a given number of cells or the rheostat set at a given point, take metallic electrodes in the dry hands and note the current; now cover the electrodes with moist flannel, and keeping the E.M.F. the same; note the increased deflection. This increase in current is due to resistance being diminished by wetting, that is to say, the high R. of the epidermis is diminished (1) by water, a fairly good conductor, getting into its interstices;* (2) by the formation of a good conducting joint; in other words, by a layer of water being interposed between the metal surface and the skin. This purpose would be better effected by using salt water instead of plain water to moisten the electrodes; but unless there is a deficiency of battery power, it is not desirable to do this as the salt solution oxidises the electrodes; and the application is more painful owing to the decomposition of sodium chloride.

To show that the physiological effect of a given current varies with "density."—The experimenter trying upon himself

* Doubtless current is to a great extent conducted by the sweat ducts.

takes a large electrode and applies it to an indifferent part of the body. For the other electrode he uses one about two inches in diameter on the cheek, and he brings the current up to a given strength, say five milliampères; then instead of the last named electrode he uses the small testing electrode in the same position, and brings the current up to the same strength as before. Note the difference in sensation, and motor effects at make and break.

Why the faradic brush is painful.—It is well known that when a current is applied by small points it is more painful than when the application is made by a flat electrode. This is due partly to the greater concentration or density of the current, and also probably to the fact that there is not a good conducting joint between the metal point and the body, and therefore small sparks leap across the space between the electrode and the sensitive tissues.

To show the effect of the superficial area of the electrodes upon current strength.—Note the difference in the deflection of the galvanometer between two small electrodes and two large electrodes, when applied to the body with a given number of cells.

How to avoid shock even in using strong currents.—It is not so much to the absolute strength and density of a steadily flowing current that the neuro-muscular system reacts, but to changes of potential (make and break) and the *suddenness* with which the change is made. Therefore in passing strong currents through the body it is absolutely necessary, in order to avoid shock, that the current be very gradually increased and very gradually diminished.

How to deal with accumulators.—Accumulators must be charged frequently, say once a month, and this whether used or not. They are usually charged from a continuous current dynamo, but any battery at a higher electro-motive force than two volts will answer the purpose.*

To charge an accumulator.—Connect the positive pole of the

* The gravity cell is suitable.

charging current with the positive pole of the accumulator, and negative pole with negative pole. One or more incandescent lamps are placed in circuit. This protects the battery and controls the rate of charging. By having an ampèremeter in circuit, and looking at it about every hour, the strength of the charging current is easily ascertained as well as its direction.

The capacity of an accumulator depends upon the size and weight of its plates and other points in its construction.* By capacity is meant the quantity of electrical energy which can, so to speak, be stored in a chemical form.

The safe current with which an accumulator may be charged or discharged depends upon the capacity of the accumulator. "As a general rule the charging current ought not to exceed one fifth, and the discharging current one quarter of the capacity."† Some accumulators are specially constructed for high rates of discharge.

Before using any particular accumulator for cautery purposes ascertain its safe rate of discharge.

For cautery purposes an accumulator ought to discharge safely up to fifteen or twenty ampères; to drive large coils up to fifteen ampères. Do not test the charge of an accumulator by joining its terminals with a wire; in other words, do not short-circuit it, this injures the plates.

Illuminating Instruments for Introduction into Cavities

In managing small surgical lamps always have a rheostat in circuit. The entire resistance should be "in" at first and gradually diminished until the carbon filament attains full incandescence, *i. e.* gets a little brighter than yellow.

The life of such lamps is from 20 to 100 hours, and their candle power is from one to five (Schall). If the lamp does not act when in position on the instrument, see first that it

* A well-designed one should be capable of giving about 5 to 7 ampère hours per pound of lead. (Dr Lewis-Jones.)

† Schall.

is properly attached, and then examine its carbon filament. If neither connections nor filament are at fault, examine the battery.

The Wehnelt Interrupter

In using high frequency currents the present writer avails himself of the new electrolytic interrupter discovered by Dr.

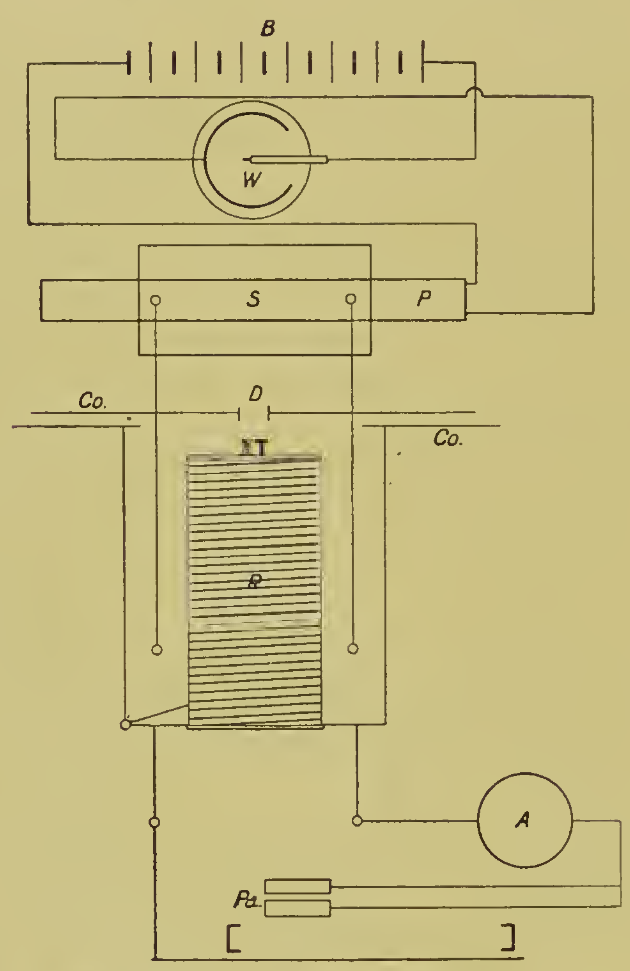

Fig. 99.—Schema for High Frequency with Electrolytic Interrupter.*

B. Battery of twenty-two cells (accumulators). W. Wehnelt interrupter. P. Primary of coil. S. Secondary of coil. D. Detonator. Co. Condensers. R. Resonator. A. Milliampère-meter. Pa. Patient. T. Terminal for monopolar treatment with electrode condenser.

When an alternating dynamo current is available, the battery, coil, and interrupter are replaced by a transformer (see p. 67).

* Installed by Mr. Dean.

Wehnelt. A useful form of this apparatus consists of a vessel filled with dilute sulphuric acid containing a large lead electrode and a small platinum one. If a considerable E.M.F.* be passed through this from a continuous current supply, the current is made and broken with extraordinary rapidity,† the rate increasing with the E.M.F. used. The current in the primary circuit is in proportion to the surface of the active electrode. Thus to regulate the rapidity it is necessary to have the E.M.F. controlled by a rheostat, and to regulate the current it must be possible to regulate the amount of active surface of the platinum electrode. The diagram (Fig. 99) shows the disposition of the apparatus for high frequency currents as used by the present writer.

* Anything above 24 volts.

† 1500 breaks a second with 100 volts (Schall.)

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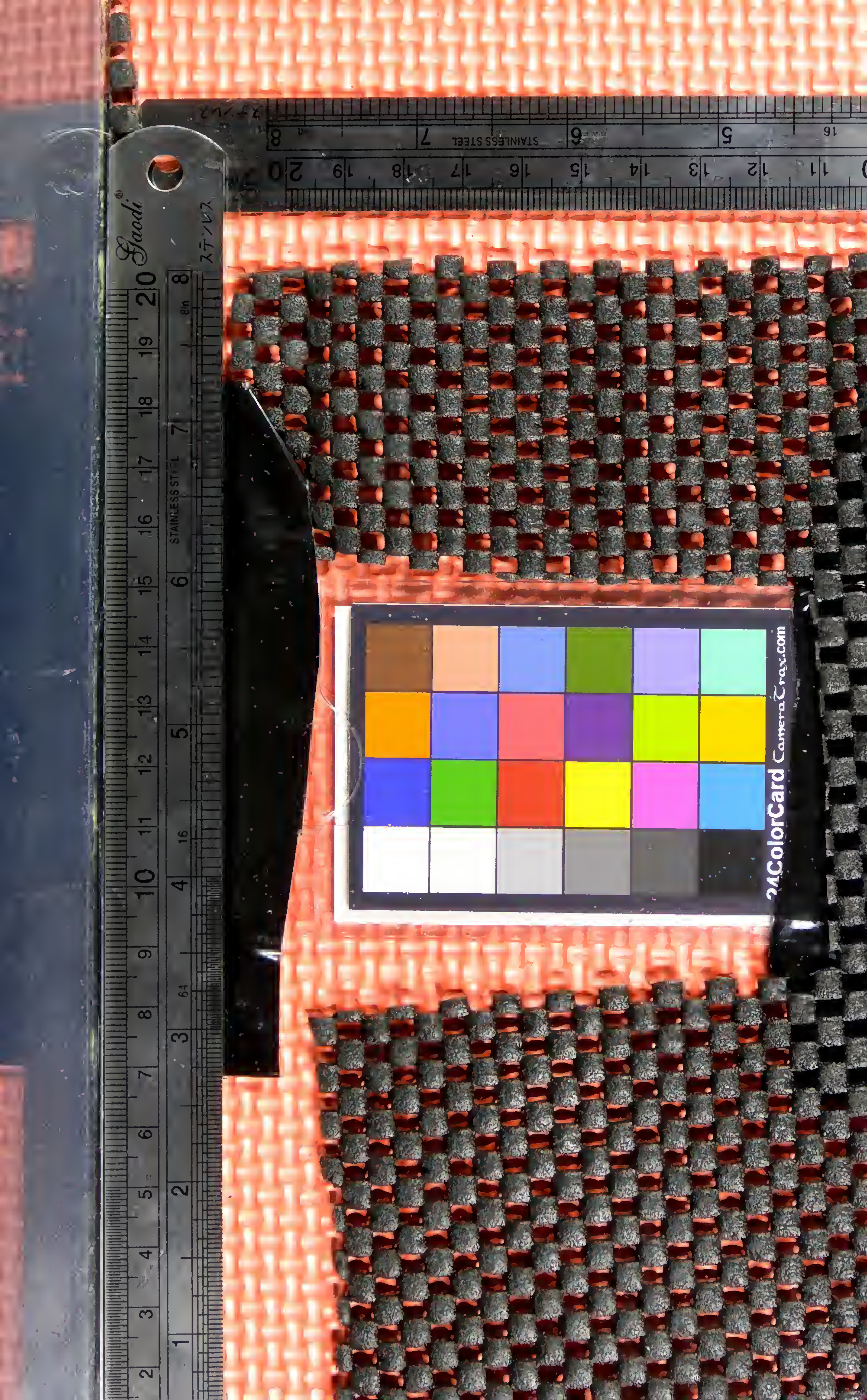
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